Contract Report _____
April 1999

Tri-Service CADD/GIS Technology Center

Tri-Service Guidelines for Installation Mapping and Geospatial Data

Approved for Public Release; Distribution is Unlimited

Published by U.S. Army Engineer Waterways Experiment Station

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Prepared by Tri-Service CADD/GIS Technology Center

U.S. Army Corps of Engineers, Waterways Experiment Station, Information Technology Laboratory

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Preface

This report provides a discussion of the procedures and standards used for the development of installation maps within the Department of Defense (DoD). The report documents the salient findings of research on installation mapping procedures, guidelines and specifications used by the DoD. It is intended to provide guidance for establishing protocols for the development of installation maps, identify appropriate geospatial data collection methods and the necessary level of detail (features) to support DoD installation mapping. This study provides the recommended guidelines for future map maintenance tasking.

This report is a product of the Tri-Service CADD/GIS Technology Center Project Number 97-027, Development of a Tri-Service Guidelines for Installation Mapping and Geospatial Data. The project was funded and conducted by the Tri-Service CADD/GIS Technology Center, Information Technology Laboratory (ITL), U.S. Army Engineer Waterways Experiment Station. The Tri-Service CADD/GIS Technology Center was chartered in 1992 to promote the use of CADD and GIS technologies for life-cycle facilities management within the Army, U.S. Army Corps of Engineers, Navy, and Air Force. The Center operates under the guidance of Dr. N. Radhakrishnan, Director, ITL, and Mr. Harold Smith, Chief, Tri-Service CADD/GIS Technology Center. The Center functions under the guidance of several oversight committees including the Executive Steering Group (ESG), Executive Working Group (EWG), Field Technical Advisory Group (FTAG).The Military Planning Field Working Group served as the project sponsor and provided technical guidance for the project. The U.S. Navy's Vanguard Mapping Process Team assisted the Military Planning Working Group in developing this product. Members of these groups are listed below.

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1. Introduction

Problem

This document provides insight into the current installation mapping practices utilized by the Department of Defense (DoD) and the four armed services (Army, Air Force, Navy, and Marine Corps). The objective of this guide is define installation map data requirements for the DoD and ensure they are aligned with the Tri-Service Spatial Data Standards (TSSDS) and the national geospatial data framework. The intent of this guide is to set a common baseline that ensures the widest utility of digital base maps for the user and customers through enhanced data sharing and the reduction of redundant data production. The *"Tri-Service Guidelines for Installation Mapping and Geospatial Data"* will provide the foundation to collect, register, and integrate digital geospatial information accurately.

Background

Computer mapping and the associated geospatial information have been generating interest for some time now. The relative uniqueness of the technology, its rapid development rate, applications developed both of commercial and military value, and the pervasiveness of this technology in other disciplines, have not been conducive to establishing a concise definition of the technology. As a matter of discussion, computer cartography or mapping should be discussed in the broader framework of Geographic Information Systems (GIS) of which mapping is a small subset. For the purpose of this guide, mapping and geospatial information will be broadly defined as a *computer system capable of holding and using geospatial information that can graphically display and/or describe the installation*. Maps are tools that provide the commanders with timely, complete, and accurate information about our installation. They have three primary uses on the installation: *locate places and features*, show *patterns of distribution* (natural and physical phenomena), and *compare and contrast* map information by visualizing the relationships between these phenomena. A map is a representation of reality comprised of selected features needed to meet the maps intended purpose.

Purpose and Scope

This guidance is intended to facilitate the interchange and use of digital installation map data. It provides technical guidance and instructions for military installation mapping tasks. With recent advancements in computer workstations and networks, the emergence of automated mapping (AM), facilities management (FM), as well as geographic information system (GIS) technologies; there are a myriad of methods being developed that supplant the traditional techniques used for the development and maintenance of installation maps. This document stresses complete and accurate reporting of information relating to quality control

and standards employed in developing and maintaining installation map data. This guidance report describes processing, accuracy, reporting, and application considerations for digital installation maps.

The Tri-Service Community is comprised of the participant designers, planners, architects, engineers and other professionals with responsibility for the military facilities of the Army, Navy, Air Force and the civil works projects of the U.S. Army Corps of Engineers. The Tri-Service Community requires guidance in the best use of these emerging technologies for installation mapping.

Applicability

This report is applicable to all DoD project management and technical personnel involved in the acquisition of installation mapping services through the use of AM/FM/GIS contractors. The report identifies the prevalent practices and standards that can be used to specify requirements for contract services and applied to installation mapping.

The intent of this report is to inform and assist DoD personnel responsible for installation mapping in the methods and techniques presently used for mapping to assist in the preparation of the technical specifications associated with acquiring mapping services. Contractors that provide installation mapping and geospatial data services will also find this report useful as it identifies the practices and standards utilized by DoD installations.

Additionally, the report will be a useful guide for the refinement of Tri-Service standards for map and geospatial data sets. Through the use of standards, it is possible to reduce the duplication of efforts associated with map production and geospatial data collection concerning an installation, between its various departments. The use of standards promotes the proper selection of mapping accuracy and appropriate level of details (data content) to meet the multi-discipline analysis applied to these geospatial data.

Related Reports and Research

The ability to use a common set of installation maps and geospatial data to plan, design, build/construct, and operate and maintain DoD facilities requires that guidelines and standards be rigorously employed in the preparation of these maps and geospatial data. For example, maps and geospatial data are commonly developed that can support an installation's multidiscipline analysis environment. That environment is driven by such specialized needs such as:

- Mission Requirements
- Installation master/comprehensive planning
- National Environmental Policy Act (NEPA) reporting
- Installation restoration program management
- Natural and cultural resource management
- Site planning and concept design
- Construction management
- Mobilization planning
- Environmental compliance
- Emergency response
- Range management

- Facilities management
- Work order management
- Privatization of Installation functions
- Base closure

Several initiatives are underway to perform research and development of viable methods and products or tools for developing and maintaining maps and other spatially referenced data to serve the installation's diverse informational needs. Considerable effort is expended in the identification of enterprise-wide solutions - where data collected once can be used by many. Enterprise-wide approaches are under development within the DoD. A few of the significant organizations researching and/or developing guidance for mapping and geospatial data maintenance within the DoD include the U.S. Air Force Center for Environmental Excellence (AFCEE), the U.S. Army Corps of Engineers Center for Public Works (CPW), Tri-Service CADD/GIS Technology Center (TSC), and the U.S. Navy's Naval Facilities Engineering Command (NAVFAC).

AFCEE develops information and provides resources and services related to Air Force wide environmental, architectural and landscape design, planning, and construction management. AFCEE has developed excellent on-line guidance for the preparation of the Installation General Plan at the Internet address http://www.afcee.brooks.af.mil. The site addresses some aspects of the development of the Air Force map series associated with installation planning and operations. Through the use of standardized planning documents and the development of tools to facilitate the standardization, the Air Force is taking an important step toward the preparation of usable spatial data on an enterprise-wide basis.

The U.S. Army Corps of Engineers Installation Support Center (ISC) has its Directorate of Public Works Automation Pamphlet available on the Internet at http://www.usacpw.belvoir.army.mil/pubs/pubs.htm. The pamphlet contains general guidance and status on current automation activities. Geospatial data systems discussed in the Automation Pamphlet include identification of the Real Property Management Tool (RMAT) and the Integrated Facilities System (IFS) which are both adopting geospatial or map based standards or guidelines for development and implementation. Additional Information is available in the ISC GIS Library at http://www.usacpw.belvoir.army.mil/pubs/pubs.htm.

ISC also has guidance associated with the preparation of the Summary Development Plan (SDP), a new master planning option. The SDP provides the Commander a one-source document that defines his long-range framework for development, e.g. essential documentation needed to explain the current status of facilities, land, and environment as these subject areas pertain to the installation and the surrounding community. The SDP is also used as a tool by the Commander to help set goals for the installation and, thus, to implement the commander's vision of the future. Information is available at http://www.usacpw.belvoir.army.mil/SDP/PAGES/Mainmenu.htm (A user name and password is required to enter this site. The user name and password can be obtained from the POC at this site).

NAVFAC has initiated Vanguard, an intranet to provide access to NAVFAC busines and facilities information for all NAVFAC employees. NAVFAC plans to expand access to its customers and suppliers through an extranet. One Vanguard initiative is the mapping process. The goals of this initiative are to develop a NAVFAC corporate strategy for preparing and maintaining Navy activity maps and to provide base maps of Navy installations to customers via the Internet.

The Tri-Service CADD/GIS Technology Center (Tri-Service Center) offers CADD, GIS and FM standards. These products are available at the Center's Internet site at the following address: http://tsc.wes.army.mil/. This Internet site includes download capabilities for the standards and technical papers that provide instruction in their use. The Tri-Service FM Standards are being developed to expand upon the GIS Spatial Data Standards to address work order management, environmental restoration tasks and environmental sampling, and other installation maintenance processes and functions that are not typically modeled through graphical depiction within a GIS. The FM Standards were under initial development at the time this report was produced.

This guide will provide the foundation on which the mapping (graphic) structure is built. It identifies common the mapping themes utilized by each of the services to produce viable maps that support mission requirements.

2 Installation Map Schema

Common Installation Geospatial Data

Collection and analysis of geospatial data are vital to the management of the installation. This effort must focus on ensuring data are available to meet the requirements of installation commander's and their subordinate units. Most of the geospatial data maintained by an installation will eventually be represented in a graphic format e.g., plan graphics, digital image, or a map. In general, an installation maintains maps that depict the following, or similar, geospatial information:

A-Natural and Cultural Resources

A-1 Areas of Critical Concern

- Historic Preservation and Archeology
- Threatened and Endangered Species
- Wetlands & Floodplains
- State Coastal Zones
- Lakes, Rivers, Streams, and Water Bodies
- Soil Borings & Soil Types

A-2 Management Areas

- Geology, including Surface Features
- Topography & Physiology
- Hydrology
- Vegetation Types
- Forest (Commercial Timber)
- Agriculture Grazing/Crops
- Fish and Wildlife
- Prime & Unique Soils
- Grounds Categories
- Climate & Weather
- Bird Aircraft Strike Hazard (BASH)
- Outdoor Recreation
- Pest Management

B-Environmental Quality

B-1 Environmental Regulatory

- Hazardous Waste Generation Points
- Permitted Hazardous Facilities
- Solid Waste Generation Points
- Solid Waste Disposal Locations
- Fuel Storage Tanks
- Installation Restoration Program (IRP)

B-2 Environmental Emissions

- Air Emission

- Waste Water NPDES Discharge

- Storm Water NPDES Discharge

- Drinking Water Supply Sources

- Electromagnetic and Radiation Sources

- Radon Sources

C-Layout and Vicinity Maps

C-1 Installation Layout

C-2 Off-base Sites

C-3 Regional Location

C-4 Vicinity Location

C-5 Aerial Photographs

C-6 Installation Boundary

D-Land Use

D-1 Existing Land Use

D-1.1 Future Land Use

D-2 Off-base Sites Land Use

D-2.1 Off-base Sites Future Land Use

D-3 Real Estate

D 4 Explosive Safety Quantity-Distance (QD) Arc

D-5 Hazard Analysis Constraints

D-6 Composite Installation Constraints and Opportunities

D-7 Area Development

E-Airfield Operations

E-1 On base Obstruction to Airfield and Airspace Criteria

E-2 Approach and Departure - Zone Obstructions to 10,000 Ft

E-3 Approach and Departure Zone Obstructions Beyond 10,000 Ft

E-4 Airspace Obstruction - Vicinity

E-5 Terminal Enroute Procedures (TERPS) Automation Plan

E-6 Airfield and Airspace Clearances

- Waivers

- Clear Zones

- Primary Surfaces

- Transitional Surface (7:1)

- Approach &Departure Surface (50:1)

- Approach and Taxiway Clearances

E-7 Airfield Pavement Plan

E-8 Airfield Pavement Details

E-9 Aircraft Parking Plan

E-9.1 Proposed Aircraft Parking Plan

E-10 Airfield Lighting Systems

F- Reserved

F-1 Reserved

F-2 Reserved

G-Utilities System Plan

G-1 Water Supply System

G-2 Sanitary Sewerage System

G-3 Storm Drainage System

G-4 Electrical Distribution System (Street & Airfield)

G-5 Central Heating and Cooling System

G-6 Natural Gas Distribution System

G-7 Liquid Fuel System

G-8 Cathodic Protection System

G-9 Cathodic Protection System Details

G-10 Industrial Waste and Drain System

G-11 Composite Utility System Constraints

G-11.1 Central Aircraft Support System

G-12 Other Utility Systems

H-Communication and NAVAID Systems

H-1 Installation Communication (Base and civilian communications units)

H-2 NAVAIDs and Weather Facilities

I-Transportation System

I-1 Community Network Access to Base

I-2 On-base Network

I-2.1 Future Transportation Plan

J-Energy Plan

K-Architectural Compatibility

L-Landscape Development Area

M-Future Development

M-1 Current Status

M-2 Short-Range Development

M-3 Long-Range Development

N-Reserved

N-*1 Reserved*

N-2 Reserved

O- Force Protection

O-1 Surge Capability (Beddown and Support of Deployed Forces)

O-2 Physical Security

O-3 Disaster Preparedness Crash Grid Map

O-4 Air Base Survivability and Theater-Specific Requirements

P - Ports and Harbors

R - Range and Training Areas

Necessary Installation Maps

Each installation is guided by its respective service's comprehensive or master planning requirements. Each installation, depending on its mission, may have substantially more or fewer theme specific maps. It is the responsibility of the installation's planning, environmental operations, engineering, and administrative staff to understand the mapping needs for their installation. Each installation is unique and the specific quantity and type of maps required for an installation depend upon its individual features, conditions and requirements. An installation will generally produce and maintain a set of maps to meet both its planning and operational needs.

The services have in the past documented their installation map requirements to support installation comprehensive planning. The Army identified guidelines for installation mapping in technical bulletins entitled Installation Master Plan Preparation (TB ENG 353) and Guidelines for the Preparation of Automated Map Databases at Army Installations (TB 5-803-3-1). While both of these documents are generally considered obsolete due to the recent technological advancements associated with digital technology and computer databases, they nevertheless offer good guidance on the salient issues of map generation for master planning purposes. The Air Force has documented mapping guidance in its "The Basic Master Statement of Work for Preparation of Comprehensive Plans for Air Force Installations." The Navy has similar guidance for its shore-based facilities and is covered in OPNAV instruction 11000.16A, titled Command Responsibility for Shore Land and Facilities Planning. It has been rewritten to address regionalization but has not been formally adopted by the Navy at the time of this writing.

Notwithstanding the various maps required by each DoD service to meet their unique and respective planning requirements, the references to the maps are also generally unique. The development of common terms of reference for map products is necessary to move toward the standardization of installation mapping. Once an accepted common mapping vocabulary is established, similarities in planning requirements will emerge. A glossary of common terms is included at the end of this document.

Table 2-1, Common Installation Map Types, provides a list of common installation maps. Included is the map name, whether the map is a mandatory or optional product as a part of the component or element plan, map scale, accuracy requirement, contour intervals, and a description of the map and its common features. As well, map data may be treated as a foundation theme that, combined or grouped, forms a composite map.

Table 2-1
Recommended Installation Maps

NOTE: UNLESS OTHERWISE SPECIFIED THE INSTALLATION LAYOUT MAP WILL BE USED AS A BASE FOR THE PREPARATION OF OTHER SPECIFIED MAPS.

MAP AND GRAPHIC LAYERS *M=mandatory* *O=optional* *TBD=to be determined*		MAP SCALE 1"=xxxx'	MAP CLASS-ACCURACY	CONTOUR INTERVAL (feet)	DESCRIPTION AND FEATURES SHOWN
A- NATURAL AND CULTURAL RESOURCES A-1 AREAS OF CRITICAL CONCERN	M	1"=400' 1:4,800	Class 1	5	Shows historic and archeological sites, areas of threatened and endangered species, primary habitat areas, flood plains, wetlands, coastal zones, lakes, rivers, water bodies, soils and soil boring locations, and similar information.
A- NATURAL AND CULTURAL RESOURCES A-2 MANAGEMENT AREAS	O	1"=400' 1:4,800	Class 1	5	Shows surface/subsurface geology, paleontology, topography, hydrology and surface drainage, vegetation areas, forests, commercial timber areas, agricultural outleasing areas, fish and wildlife areas, prime soils, grounds maintenance areas, outdoor recreation areas, pest management areas, and similar information.

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NOTE: UNLESS OTHERWISE SPECIFIED THE INSTALLATION LAYOUT MAP WILL BE USED AS A BASE FOR THE PREPARATION OF OTHER SPECIFIED MAPS.

B- ENVIRONMENTAL QUALITY B-1 ENVIRONMENTAL REGULATORY AREAS	M	1"=400' 1:4,800	Class 1	5	Shows hazardous waste generation points, hazardous waste storage facilities, solid waste disposal and recycling points, fuel tanks, Resource Conservation and Recovery Act sites, installation restoration program sites/areas, and similar information.
B- ENVIRONMENTAL QUALITY B-2 ENVIRONMENTAL EMISSIONS AREAS	O	1"=400' 1:4,800	Class 1	5	Shows sources of air emissions, wastewater Non-point Pollution Discharge Elimination System (NPDES) point source discharges, storm water non-point discharges, drinking water supply, electromagnetic radiation sources, sources of radon emissions and similar information.
C-INSTALLATION LAYOUT AND VICINITY C-1 INSTALLATION LAYOUT	M	1"=100' 1:1,200	Class 1	2	Shows the installation boundary; buildings (facility identification numbers and type: permanent, semi-permanent, temporary); structures; roads and parking areas; walkways and trails; railroads; fences; recreation areas; cemeteries; training ranges; contours; water areas; coordinate grid; embankments; below/above ground tanks; embankments; spot elevations and survey control; neighboring land use (outside installation boundary); historic buildings and places, archeological sites and similar information.
C-INSTALLATION LAYOUT AND VICINITY C-2 OFF-INSTALLATION SITES	M	1"=400' 1:4,800	Class 1	5	Shows the same information as the installation layout map, but this map is prepared for those facilities that are outside the installation's primary boundary.
C-INSTALLATION LAYOUT AND VICINITY C-3 INSTALLATION REGIONAL LOCATION	O	1"=2,000' 1:24,000	NA	20	Shows information of interest to regional planning and major transportation systems, cities, towns, political jurisdictions, DoD installation boundaries, aeronautical data, woodlands, recreation areas, towers, significant physical characteristics of the region and other similar information.
C-INSTALLATION LAYOUT AND VICINITY C-4 INSTALLATION VICINITY	O	1"=1000' 1:12,000	Class 1	10	Shows the installation boundary, airfield and operations areas, major roads, proposed roads and highways, railroads, bombing and test ranges, vertical obstructions, topography, recreation areas, waterways and bodies, towers and similar information.

Table 2-1
Recommended Installation Maps

NOTE: UNLESS OTHERWISE SPECIFIED THE INSTALLATION LAYOUT MAP WILL BE USED AS A BASE FOR THE PREPARATION OF OTHER SPECIFIED MAPS.

C-INSTALLATION LAYOUT AND VICINITY C-5 AERIAL PHOTOGRAPHIC COVERAGE AND CONTROL STATIONS	O		NA	NA	Prepared as an index of the aerial photographic coverage for the installation, shows the center point of individual photographs as well as the location of survey control stations and control points used for the aerial photography.
C-INSTALLATION LAYOUT AND VICINITY C-6 INSTALLATION BOUNDARY	M	Legal Records	Class 1	1	Shows the land area comprising the installation boundary including survey monuments.
D- LAND USE D-1 INSTALLATION LAND USE D-1.1 FUTURE LAND USE	M	1"=400' 1:4,800	Class 1	5	Shows installation land use including airfields; maintenance and repair areas; manufacturing industrial areas; supply/ storage areas; administration areas; training and ranges areas; troop and family housing; community facilities (commercial and service); medical facilities; outdoor recreation; open spaces; and similar information
D- LAND USE D-2 OFF SITE LAND USE D-2.1 FUTURE OFF SITE LAND USE	O	1"=400' 1:4,800	Class 1	5	Shows off-site land use including airfields; maintenance and repair areas; manufacturing industrial areas; supply/ storage areas; administration areas; training and ranges areas; troop and family housing; community facilities (commercial and service); medical facilities; outdoor recreation; open spaces; and similar information
D- LAND USE D-3 REAL ESTATE	O	1"=400' 1:4,800	Class 1	2	Shows the land area comprising the installation including parcel information on fee title, lease, license, permit and easement areas inclusive of tract, acreage, data of acquisition, lease period and similar information.
D- LAND USE D-4 EXPLOSIVE SAFETY QUANTITY-DISTANCE CLEARANCE ZONES (QD-ARCS)	M	1"=400' 1:4,800	Class 1	5	Same as installation layout map, but includes the distance clearance zones for explosives.
D- LAND USE D-5 HAZARD ANALYSIS CONSTRAINTS	M	1"=400' 1:4,800	Class 1	5	Same as installation layout map, but includes areas of catastrophic potential to include flooding, subsidence, avalanche, erosion, earthquake, tsunami, snowfall, windstorm, volcanic ash and similar information.
D- LAND USE D-6 COMPOSITE CONSTRAINTS	M	1"=400' 1:4,800	Class 1	5	Same as installation layout map, but emphasizes areas of catastrophic potential from natural occurrences e.g., flooding, subsidence, avalanche, earthquake, tsunami and technological occurrences, accident potential zones, hazardous noise

Table 2-1
Recommended Installation Maps

NOTE: UNLESS OTHERWISE SPECIFIED THE INSTALLATION LAYOUT MAP WILL BE USED AS A BASE FOR THE PREPARATION OF OTHER SPECIFIED MAPS.

					areas, noise contours, environmental management areas and other similar information.
D- LAND USE D-7 AREA DEVELOPMENT	O	1"=100' 1:1,200	Class 1	2	Same as installation layout map, but includes information on the planned development of areas within the installation.
E-AIRFIELD OPERATIONS E-1 ON-BASE OBSTRUCTIONS TO AIRFIELD CRITERIA	M	1"=1,000' 1:12,000	Class 1	5	Same as airport pavement map and includes information on any obstructions to navigation and ground movement of aircraft within the installation boundary.
E-AIRFIELD OPERATIONS E-2 APPROACH/DEPARTURE ZONE OBSTRUCTIONS (to 10,000 feet)	M	1"=800'	Class 1	5	Shows obstructions within the glide angle approach zone and other similar information within the distance specified.
E-AIRFIELD OPERATIONS E-3 APPROACH/DEPARTURE ZONE OBSTRUCTIONS (from 10,000 feet to 10 miles)	M	1"=2,000' 1:24,000	Class 1	10	Shows obstructions within the glide angle approach zone and other similar information within the distance specified.
E-AIRFIELD OPERATIONS E-4 AIRSPACE OBSTRUCTION-VICINITY	M	1"=1,000' 1:12,000	Class 1	10	Shows obstructions within the vicinity of the airfield, but not those already shown on approach/departure zone maps, topography, cities, towns, other obstructions, water courses and water bodies and similar information.
E-AIRFIELD OPERATIONS E-5 TERMINAL ENROUTE PROCEDURES (TERPS) AUTOMATION	M	TBD	TBD	TBD	Shows all NAVAIDS with latitude and longitude.
E-AIRFIELD OPERATIONS E-6 AIRFIELD/AIRSPACE CLEARANCES	O	1"=100' 1:1,200	Class 1	2	Shows airfield waivers, clear zones, primary surface, transitional surface (7:1), approach and departure surface (50:1) approach and taxiway clearances, wing tip clearances, turning radii, and other similar information necessary for aircraft movement on the ground.
E-AIRFIELD OPERATIONS E-7 AIRFIELD PAVEMENT	O	1"=400' 1:4,800	Class 1	5	Shows runways, taxiways, aprons, warm-up pads, hardstands, helipads, stabilized shoulders, overruns and similar information.
E-AIRFIELD OPERATIONS E-8 AIRFIELD PAVEMENT DETAILS	O	1"=100' 1:1,200	Class 1	2	Shows runways, taxiways, aprons, warm-up pads, hardstands, helipads, stabilized shoulders, overruns and similar information, but includes cross sections and elevation profiles.
E-AIRFIELD OPERATIONS E-9 AIRCRAFT PARKING E-9.1 PROPOSED AIRCRAFT PARKING	O	1"=100' 1:1,200	Class 1	2	Shows the parking plan for aircraft including alert hangars, refueling outlets, blast fences, aircraft orientation, control tower, fire station,

Table 2-1
Recommended Installation Maps

NOTE: UNLESS OTHERWISE SPECIFIED THE INSTALLATION LAYOUT MAP WILL BE USED AS A BASE FOR THE PREPARATION OF OTHER SPECIFIED MAPS.

					cargo holding pads, maintenance docks, maintenance lights, aircraft revetments and similar information.
E-AIRFIELD OPERATIONS E-10 AIRFIELD LIGHTING SYSTEMS	O	1"=100' 1:1,200	Class 1	2	Shows the major components of airfield lighting system including runway, taxiway, end reference lights, location size and type of underground ducts, obstruction lights, stand-by generator equipment and similar information.
F- Reserved					
G-UTILITY SYSTEMS G-1 WATER SUPPLY SYSTEM	M	1"=50' 1:600	Class 1	1	Shows all significant components of the water supply system.
G-UTILITY SYSTEMS G-2 SANITARY SEWERAGE SYSTEM	M	1"=50' 1:600	Class 1	1	Shows all significant components of the sanitary sewerage system.
G-UTILITY SYSTEMS G-3 STORM DRAINAGE SYSTEM	M	1"=50' 1:600	Class 1	1	Shows all significant components of the storm drainage system.
G-UTILITY SYSTEMS G-4 ELECTRICAL DISTRIBUTION SYSTEM (STREET AND AIRFIELD)	M	1"=50' 1:600	Class 1	2	Shows all significant components of the electrical distribution and exterior lighting systems.
G-UTILITY SYSTEMS G-5 CENTRAL HEATING/COOLING SYSTEMS	M	1"=50' 1:600	Class 1	1	Shows all significant components of the central heating/cooling systems.
G-UTILITY SYSTEMS G-6 NATURAL GAS DISTRIBUTION SYSTEM	M	1"=50' 1:600	Class 1	2	Shows all significant components of the natural gas distribution system.
G-UTILITY SYSTEMS G-7 LIQUID FUEL SYSTEM	M	1"=50' 1:600	Class 1	1	Shows all significant components of the liquid fuel system.
G-UTILITY SYSTEMS G-8 CATHODIC PROTECTION SYSTEM	O	1"=100' 1:1,200	Class 1	2	Shows all significant components of the cathodic protection system for all underground utility systems and structures subject to electrochemical corrosion .
G-UTILITY SYSTEMS G-9 CATHODIC PROTECTION SYSTEM DETAILS	O	1"=50' 1:600	Class 1	2	Shows all significant components of the cathodic protection system including details of other utilities in proximity to ground beds for all underground utility systems.
G-UTILITY SYSTEMS G-10 INDUSTRIAL WASTE AND DRAIN SYSTEM	O	1"=50' 1:600	Class 1	2	Prepared when these systems are of such a complexity or nature it requires the production of a separate map to portray their characteristics.
G-UTILITY SYSTEMS G-11 COMPOSITE UTILITY SYSTEM	M	1"=100' 1:1,200	Class 1	2	Shows the water, sanitary sewer, storm drainage, electrical, central heating/cooling, gas compressed air, industrial waste and other utility systems combined on a single map.

Table 2-1
Recommended Installation Maps

NOTE: UNLESS OTHERWISE SPECIFIED THE INSTALLATION LAYOUT MAP WILL BE USED AS A BASE FOR THE PREPARATION OF OTHER SPECIFIED MAPS.

G-UTILITY SYSTEMS G-11.1 CENTRAL AIRCRAFT SUPPORT SYSTEMS	O	1"=50' 1:600	Class 1	2	Shows all the utilities systems that serve the airfield apron and related servicing of aircraft.
G-UTILITY SYSTEMS G-12 FIRE PROTECTION SYSTEMS AND UTILITIES	M	1"=400' 1:4,800	Class 1	5	Shows fire hydrants, water deluge systems, safety buffer distances, vehicle maneuverability areas, and similar information related to fire protection or safety.
G-UTILITY SYSTEMS G-13 OTHER UTILITY SYSTEMS	O	1"=100' 1:1,200	Class 1	2	Show utilities not displayed on other maps.
H-COMMUNICATION AND NAVAID SYSTEMS H-1 INSTALLATION-WIDE COMMUNICATIONS AND COMPUTER SYSTEMS	M	1"=400' 1:4,800	Class 1	5	Uses the installation layout map as a base to show installation-wide communications systems.
H-COMMUNICATION AND NAVAID SYSTEMS H-2 NAVAID SYSTEMS	M	1"=400' 1:4,800	Class 1	5	Shows NAVAID components such as radio transmitters, radio relay facilities, high and ultra high frequency direction finders, radio beacon shelters, GCA units, RAPCON units, PAR structures, TACAN buildings and facilities and similar information.
I-TRANSPORTATION SYSTEM I-1 COMMUNITY NETWORK - ACCESS TO BASE	M	1"=400' 1:4,800	Class 1	10	Shows all major arterial, collector streets that have direct relationship to the installation and local streets providing access to the installation.
I-TRANSPORTATION SYSTEM I-2 ON-BASE NETWORK	M	1"=400' 1:4,800	Class 1	2	Shows the transportation network including parking areas, sidewalks, bike/hike/jogging trails on the installation.
I-TRANSPORTATION SYSTEM I-2.1 FUTURE ON-BASE NETWORK	O	1"=400' 1:4,800	Class 1	2	Shows the planned transportation network including parking areas, sidewalks, bike/hike/jogging trails on the installation.
J-ENERGY SYSTEMS	O	1"=100' 1:1,200	Class 1	2	Shows data related to the installation's energy planning systems.
K-ARCHITECTURAL COMPATIBILITY	O	1"=400' 1:4,800	Class 1	2	Shows the installation's architectural compatibility zones and architectural districts.
L-INSTALLATION LANDSCAPE DEVELOPMENT AREA	O	1"=400' 1:4,800	Class 1	2	Shows the installation's landscape areas and planned flora.
M-FUTURE DEVELOPMENT M-1 CURRENT	M	1"=400' 1:4,800	Class 1	5	Shows the current installation layout; e.g. streets, parking lots, buildings, utilities etc, to include those facilities presently under development.

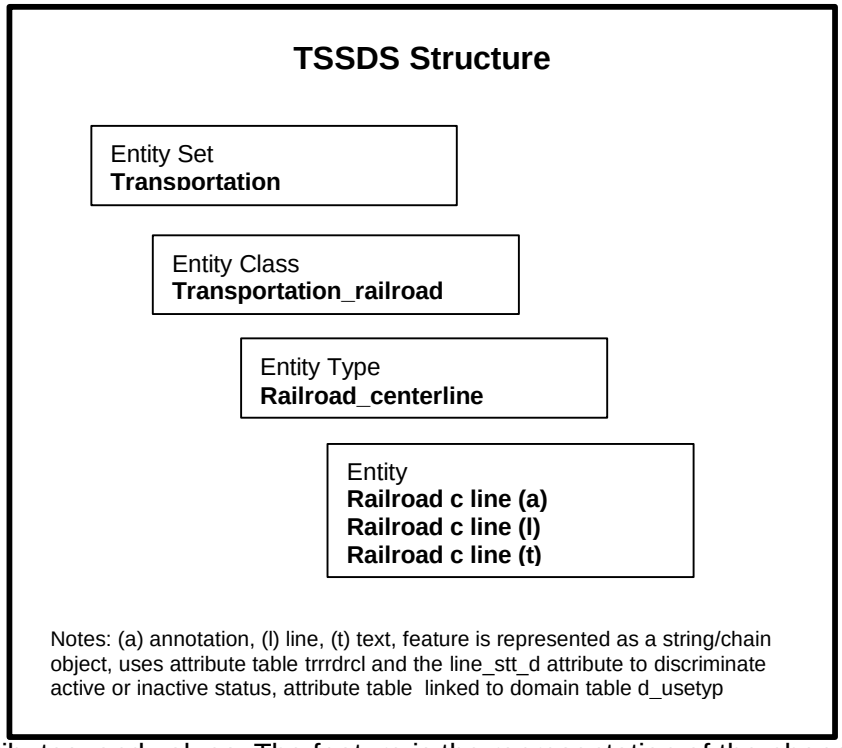
Table 2-1
Recommended Installation Maps

NOTE: UNLESS OTHERWISE SPECIFIED THE INSTALLATION LAYOUT MAP WILL BE USED AS A BASE FOR THE PREPARATION OF OTHER SPECIFIED MAPS.

M-FUTURE DEVELOPMENT M-2 FUTURE DEVELOPMENT SHORT-TERM (1-5 YEARS)	M	1"=400' 1:4,800	Class 1	5	Shows planned development on the installation including streets and parking lots, buildings, utilities and similar information.
M-FUTURE DEVELOPMENT M-2 FUTURE DEVELOPMENT SHORT-TERM (> 5 YEARS)	M	1"=400' 1:4,800	Class 1	5	Shows the facilities that will be developed beyond a five-year time frame on the installation including streets and parking lots, buildings, utilities and similar information.
O-FORCE PROTECTION 0-1 SURGE CAPABILITY (BEDDOWN AND SUPPORT)	O	1"=400' 1:4,800	Class 1	5	Show areas that can be suited for temporary billeting of troops in the case of surge requirements.
O-FORCE PROTECTION 0-2 PHYSICAL SECURITY	M	1"=400' 1:4,800	Class 1	5	Shows security fences, proposed and existing access points, sensor devices, location of security police units, fire stations and other similar information.
O-FORCE PROTECTION 0-3 DISASTER PREPAREDNESS CRASH GRID	M	1"=400' 1:4,800	Class 1	5	Shows all buildings and building numbers with hospitals and fallout shelters, protection factors and similar information.
O-FORCE PROTECTION 0-4 INSTALLATION SURVIVABILITY	O	1"=400' 1:4,800	Class 1	5	Prepared for installations to show operational contingencies.
P-PORTS AND HARBORS	O	1"=100' 1:1,200	Class 1	2	Shows berths, breakwater, channel, cable and pipeline areas, hazard areas, dry dock, navigation aides, jetties, wrecks, bouys, piers, quays, reefs, safety fairway, wharf, and other similar information.
R-RANGE AND TRAINING AREAS R-1 RANGE AREA	0	1"=400' 1:4,800	Class 1	5	Shows surface danger zones, target areas, impact areas, dudded areas, bomb circles, firing points, firing fans and lanes, range control points, and other similar information.
R-RANGE AND TRAINING AREAS R-2 TRAINING AREA	0	1"=400' 1:4,800	Class 1	5	Shows landing zones, drop zones, bivouac areas, training sites, foot traffic areas, perimeter defense, obstacle course areas, drill fields, marching areas and other similar information.

TSSDS Schema

While assembling the installation's mapping needs, it was apparent that a standardized database schema would facilitate sharing data between agencies, installations, and even across the services. Like the mapping structure discussed in the preceding section, the TSSDS uses a similar methodology for distinguishing various types of geospatial data. The overall structure of the Tri-Service Spatial Data Standards is based upon the concept of



features, attributes, and values. The feature is the representation of the phenomenon as it exists in the real world; in the TSSDS this is known as a discriminated entity type. These features are organized into thematic groups or sets, then into maps or classes, and finally into types or coverage's. The figure below outlines the overall organization of these elements giving an example from the transportation entity set for a railroad centerline feature.

The TSSDS uses "entity sets" to classify graphic (maps) and non-graphic data (tabular files, reports, database files etc). There are a total of 24 entity sets in the TSSDS (see below). For the novice, it is helpful to think of an "entity set" as a map display. For example, the installation has identified the maps needed to meet mission requirements. One set of information needed by the base is a map of the transportation network that supports the base, a map that shows how people and supplies enter and leave the base. In this case, the entity set is transportation. It contains all forms of transportation to include airfields, roads, railroads, and ports and harbors. In order to examine an individual or separate transportation network, such as railroads, we need to go to the next level within the TSSDS.

Auditory
Boundary
Buildings
Cadastre
Climate
Common
Communications
Cultural
Demographic
Environmental
Hazards
Flora
Fauna
Geodetic
Geology
Hydrography
Improvement
Land Use
Landform
Military Operations
Olfactory
Soil
Transportation
Utilities
Visual

The next lower level of geographical features within the TSSDS is the "entity class". For our example, this is the railroad network. This map will display the entire railroad system. The individual items that comprise the railroad system e.g., rails, centerline, spurs, gates,

right of way, and roundhouses are referred to as "entity types". An entity type is the logical name of an object that can be graphically depicted on maps or overlays.

Below the "entity type" is the entity. An entity is a further breakdown of the geospatial image shown on the map. Using the same example from above, the entity would depict multiple or single tracks, abandoned or active tracks.

For general map tasking, some understanding of attributes is necessary, as some entities will usually require limited attribute data population during the mapping task. An entity is an individual data element containing information regarding a geo-spatial object or entity_type. An attribute contains values (or no value) based on the characteristics of the attribute. Attributes may be either numeric of varying precision or character. The precise data type of the attribute is a function of the Relational Database Management System (RDBMS) used to store the attached attribute data. Attributes may also have Domains, which contain lists of acceptable values for the attribute or define a range of acceptable numeric values. Domains can be of the list or range type.

The Tri-Service CADD/GIS Technology Center has available on its web site for download implementation guidance for the MGE, ARC/INFO, and ArcView software. To gain an appreciable understanding of how to implement projects using the TSSDS, this guidance should be used. The reports are available at **http://tsc.wes.army.mil**.

For installations that already possess mapping or geospatial data sets, the migration to the TSSDS is more complex to implement. This migration complexity is due to the non-uniformity of structure, in virtually all cases, of graphic file and associated RDBMS tables with the TSSDS. It is best that a strategy be well planned and documented prior to undertaking such a migration. Priorities must be set and weighed carefully against the benefits of migration. In many cases, some legacy databases may not be suitable for migration, especially if the databases have a “flat file” non-relational format or the context is of questionable accuracy.

A tremendous effort can be associated with migration, even in cases of pure graphical data. Careful planning under the guidance of competent staff, an A-E contractor, or through support from the Tri-Service CADD/GIS Technology Center is a necessity with most migration efforts. It is recommended that a correlation be prepared for all graphic files and database tables before migration is performed. The correlation should include, as a minimum, the feature to feature, entity type to entity type, attribute to attribute, and domain table to domain table comparison. From this correlation, an appropriate migration strategy can be developed.

Relationship of TSSDS Schema with Installation Mapping Requirements

As stated earlier, the TSSDS entity set can generally be thought of as a map. However, there is no direct correlation between the references to TSSDS entity classes and the installation mapping requirements currently specified within the guidance for an Air Force General or Army Master plan. Specifically, in release 1.75 of the TSSDS there are 123 entity classes. A list of the entity classes with associated map name prefixes is contained in Appendix A, TSSDS Map Name Prefix Schema.

Of those 123 entity classes, three within the common entity set (common_general, common_metadata, and common_dictionary) possess data that is generally not best represented on a map. So there are approximately 120 maps that are specified within the TSSDS that could be produced for an installation, if the installation had all conceivable occurrences of geospatial data of the type represented by the entity classes. As evidenced by the number of entity classes, installation mapping requirements could be enormous to perform and maintain.

The Air Force General Plan presently specifies over sixty thematic maps that could be prepared for an installation. The Army specifies twenty existing condition maps within its Master Planning Guidance. Navy personnel are currently addressing their mapping needs and have identified twenty-two potential thematic maps. It is important that the DoD services understand the relationship of the TSSDS to their respective planning and operational map tasking requirements and that future furnished DoD guidance accurately reflects the requirements contained within the TSSDS.

3 Guidelines for the Preparation of Installation Maps and Geospatial Data

Map Basics

The term “map” refers to a two-dimensional graphic image, which shows the location of things in space, that is, in relationship to the Earth’s surface (Keates). A typical map uses an orthogonal viewpoint - where every point on the map is viewed as if looking straight down from above - to represent the Earth’s three-dimensional surface onto a plane. It does not describe or depict individual features, but represents them by symbols, e.g., points, lines, polygons, area patterns and colors etc., that place them into classes or categories. Maps are unlike photographs. Where a photograph shows all objects in its view, a map is a simple abstraction of reality. A map can be made to represent the subject that is of interest to the user or reviewer. Maps are the most common graphic used for installation planning.

Map Scales

Scale is used to establish the relationship between the distance of two points on the earth and the distance between two corresponding points on the map. As a rule, scale is referred to as a numerical ratio of map distance to ground distance. It is usually written as 1/24,000 or 1:24,000, meaning that one unit of measurement on the map represents 24,000 of the same units on the ground. Maps should be prepared at a scale appropriate for the information or subject being illustrated. When scale is expressed in words, for example one inch equals 50 feet, it is referred to as a verbal scale. The bar scale or visual scale can be used for measuring distance. It graphically displays the relationship between map distance and ground distance.

The ranges of map scale are defined as large scale and small scale. The map series shown in Figures 3-1 and 3-2 demonstrate the effect of zooming "in" or "out" from the surface of the earth. A large-scale map shows a small area with a large amount of detail, e.g. small area development map, or a site plan.

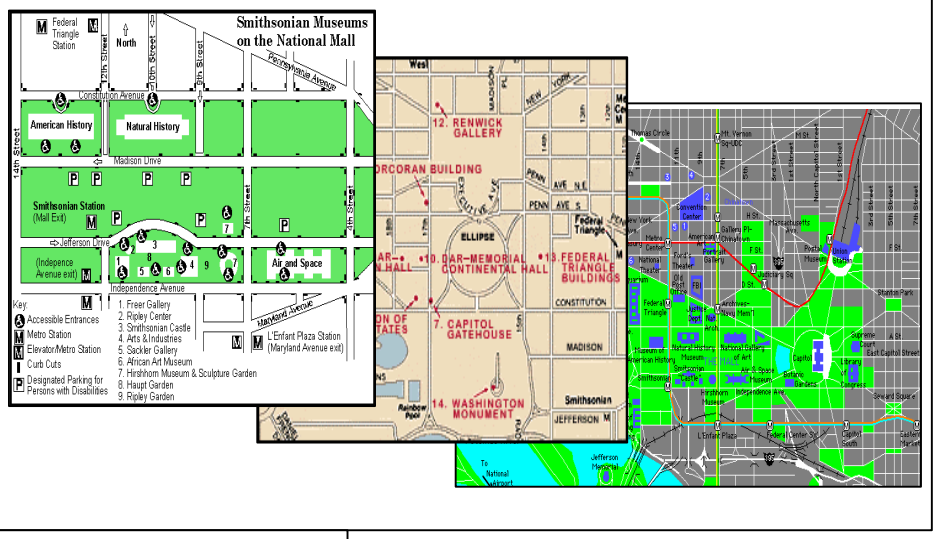


Figure 3-1 Large Scale Maps

A small-scale map "zooms out" from the source, displaying a larger area with a small amount of detail. For an installation, a small-scale map would be comparable to a "regional map" showing the relationship of the installation to the surrounding area.

Figure 3-2 Small Scale Map

Usually specific small-scale mapping projects are not performed for military installations. Maps of the installation are normally produced at larger scales. Small-scale maps are appropriate when it is necessary to show the entire region on a single map for a macro review of subject themes such as the following:

- regional setting
- transportation profile
- change detection (natural resources)

- environmental control

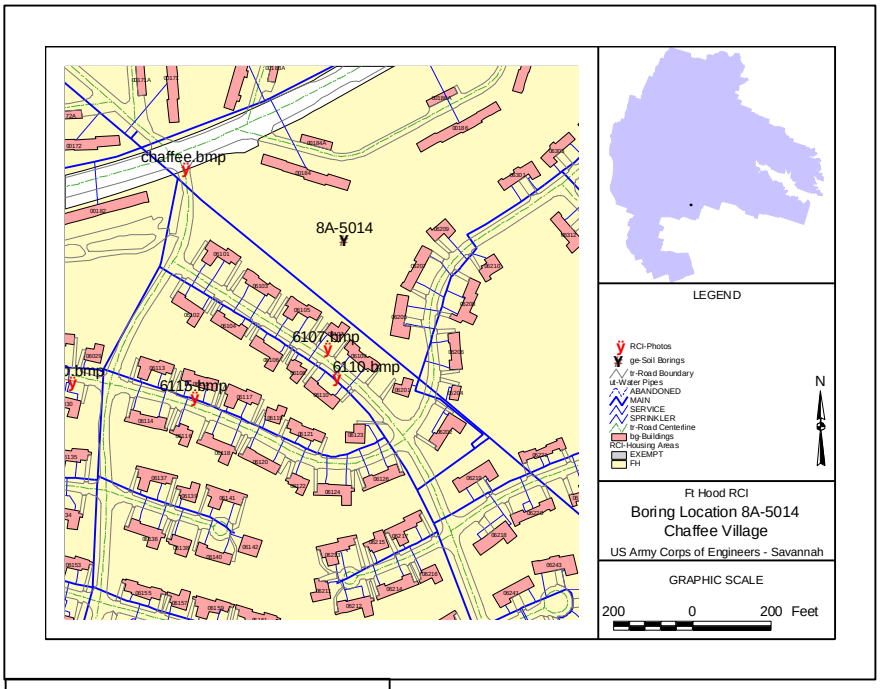


Figure 3-3 Map Composition

It is appropriate that all maps be prepared with a legend to describe the depicted themes, a bar scale or note specifying the map scale, and a north arrow that orientates the map. A bar scale is preferred over a scale note, as maps are often photographically copied, enlarged or reduced. The bar scale maintains the appropriate reference to scale as the copy, enlargement, or reduction is applied. A note cannot maintain this relationship.

Map users should be aware that any copied map, even with a bar scale on the map, might have an actual map scale that could vary from the original. This variation is due to distortions inherent in the reproduction process. This is especially true if maps are copied, enlarged, or reduced on a common copy machine. If the scale of the copy is not certain, then the labels such as “Not to Scale” or a label, such as 1”= approximately 50’, should be used.

The next section provides a discussion of accuracy considerations, specifications and classes, which affect the original production, and reproduction of maps. The user of any map product, especially one reproduced from enlargement or reduction, should be aware of the potential for the introduction of inaccuracy into such products.

Accuracy Considerations

The Department of Defense (DoD) has not adopted a specific mapping standard of its own. In lieu of establishing a separate standard, DoD uses the guidance contained in the Office of Management and Budget (OMB Circular No. A-119, ***Federal Participation in the Development and Use of Voluntary Standards***. This circular prescribes that federal

agencies maximize the use of industry standards. "Specifications for surveying and mapping shall use industry consensus standards established by national professional organizations such as The American Society of Photogrammetry and Remote Sensing (ASPRS)..."There are several professional groups that have established "industry" standards. The Army Corps of Engineers have adopted the ASPRS standards for large scale mapping (***areas under 10,000 acres***). The Departments of the Army, Navy, and Air Force follow suit on this adoption.

Horizontal accuracy requirements are established by the ASPRS Horizontal (planimetric) Standards for Large Scale Mapping (Appendix C). These limits of accuracy pertain to well-defined map test points only. Horizontal spatial accuracy is defined as the circular error of a data set's horizontal coordinates at the 95% confidence level. As depicted in Figure 3-4a, using second order survey ground control marks, the probability distribution for a point is +/- 40' using a 1:24,000 (1"=2,000') scale map.

Vertical spatial accuracy is established by the ASPRS Vertical (Topographic) Standards for Large Scale Mapping (Appendix C) is defined by the linear error of a data set's vertical coordinates at the 95% confidence level. As shown in Figure 3-4b, using second-order survey ground control markers, the probability distribution for a line is +/- 40' using a 1:24,000 (1"=2,000') scale map.

Basically this means, that when we see a point (feature) on a map we know we have the "probable" location within certain limits - in the examples below we have the probable location of the feature within 40 feet. Caution must be exercised here. We must remain cognizant of the dangers of false accuracy--that is reading locational information from map levels of accuracy beyond which they were created. This is inherent in computer systems that allow the user to pan and zoom at will to an infinite number of scales.

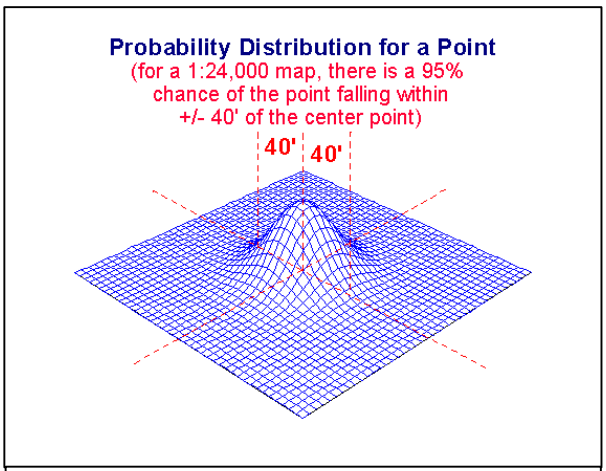


Figure 3-4a Point Probability

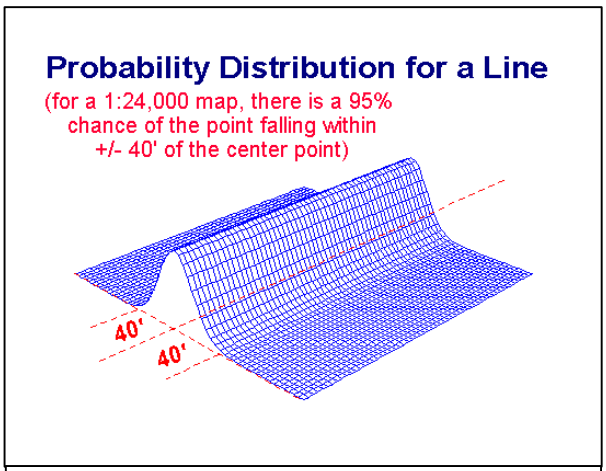


Figure3-4b Line Probability

Accuracy is tied to the original map scale and does not change even if the user zooms in and out. Zooming in and out can mislead the user into the false belief that the accuracy has improved. See Figure 3-5.

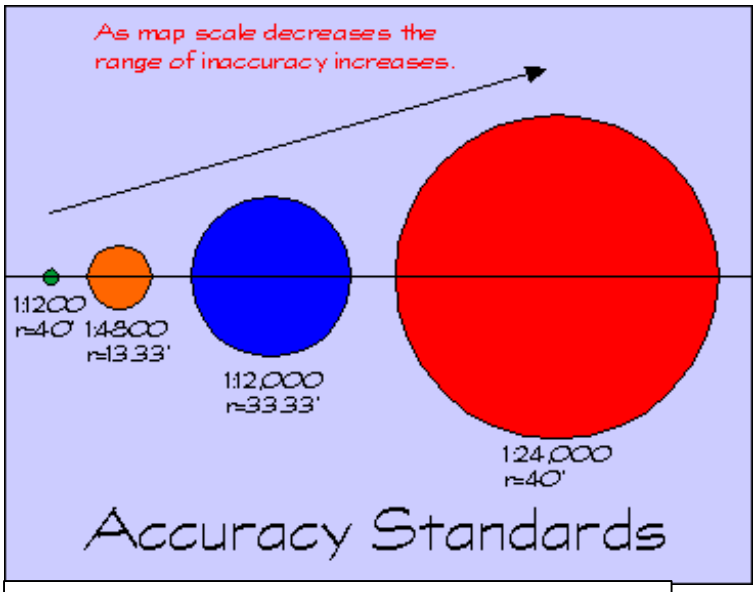


Figure 3-5 Map Accuracy VS Map Scale

Accuracy reported at the 95% confidence level means that 95% of positional accuracy would be equal to or smaller than the reported accuracy value. The reported accuracy value is the cumulative result of all uncertainties, including those introduced by local project control coordinates, field topographic surveys, photogrammetric compilation, or final extraction of ground coordinate values in the spatial data. The reference scheme for radial or linear errors must be defined as relative to absolute geospatial reference networks or local (internal construction) schemes. Spatial data may be compiled to comply with one level of accuracy in the vertical component and another in the horizontal component. In both cases, establishing well-defined ground control points is necessary to develop the horizontal and vertical accuracy needed by military installations.

It is essential that mapping and surveying specifications originate from the functional requirements of the project, and that these requirements are realistic and economical. Specifying mapping accuracy in excess of those needed to accomplish the work results in increased costs. See Table 3-1 for general guidance on mapping scales and accuracies. Even at scales where centimeter accuracy is allowable, it may be unnecessary or impractical to develop products to that accuracy due to excessive cost, time, or perhaps more importantly, the lack of justifiable need. Again, it is essential that the map be developed at a scale appropriate for its intended purpose and that the map's accuracy meets existing standards or specifications.

Map Accuracy Specifications

Standards have been established for the expected accuracy for maps regardless of scale. These standards have been developed so users of maps are able to use the products with confidence. Map standards are usually given in terms of an allowable error at a specific scale. The American Society for Photogrammetry and Remote Sensing (ASPRS) Map Accuracy Specifications state that the following maximum errors are permitted on maps:

Horizontal accuracy. The ASPRS standards state that 95% of all planimetric features that are well defined on the photographs (assumes using photogrammetric techniques for map production) shall be plotted so that their position on the finished maps shall be accurate to within at least 1/40" of their true coordinate position, as determined by test surveys, and none of the features tested shall be misplaced by more that 1/20" from their true coordinate position.

Vertical accuracy. The ASPRS states that 95% of the elevations determined from solid-line contours (dashed contour lines usually indicate approximate elevations) of the topographic maps shall have an accuracy with respect to true elevation of ½ the contour interval or better and the remaining 10% of such elevations shall not be in error by more than one contour interval. Furthermore, 95% of the shown spot elevations must have an accuracy of at least ¼ the contour interval, and the remaining shall not be in error by more than ½ the contour interval.

Accuracy Classes

The U.S. Army Corps of Engineers' Photogrammetric Mapping, Engineer Manual refers to accuracy standards for large-scale maps that consist of three levels. Class 1 is the most accurate, while class 2 accuracy has an allowable Root Mean Square Error (RMSE) that is twice that if the Class 1 map. Class 3 has an allowable RMSE three times that of the Class 1 map. Maps may be in one class in horizontal accuracy and another in vertical.

The RMSE is defined to be the square root of the average of the squared discrepancies. While the discrepancies are the differences in the coordinates or elevation values as determined by an independent survey of higher accuracy. The RMSE is defined in terms of feet or meters at ground scale. So, as map scale decrease the RMSE increases in a linear relationship. See Figure 3-5, Map Accuracy vs. Map Scale, for graphic depiction of this concept. Table 3-1 shows the maximum permissible RMSE for well-defined points as established by the standard.

There are some common understandings related to aerial mapping practices and the use of standards. For example, to obtain a 3 foot contour interval it is accepted that you fly photography at a scale no greater than 1:1,200 (when using analytical stereo-plotting instruments to produce the map). So 1:1,200 scale maps are generally accepted to require 3 foot contours. 1:600 maps get a 1.5 foot contour, 1:2,400 scale map can get a 6 foot contour and 1:60,000 scale maps a 30 foot contour. A 1:100,000 scale map usually will have a 150 foot contour. Another rule of thumb is that a map produced on an analytical stereo-plotter (unlike a digital orthogonal discussed earlier in this report) should not be produced at a scale larger than six times the original data acquisition scale. So good quality 1:3,000 scale aerial photography could be used to produce a map at 1:600 (1"=50').

Table 3-1

Planimetric Feature Coordinate Accuracy Requirement (Ground X or Y in Feet) for Well-Defined Points

Target Map Scale	Limiting RMSE in X or Y			
1"=x'	Ratio, ft/ft	Class1	Class 2	Class 3
5	1:60	0.05	0.10	0.15
10	1:120	0.10	0.20	0.30
20	1:240	0.2	0.4	0.6
30	1:360	0.3	0.6	0.9
40	1:480	0.4	0.8	1.2
50	1:600	0.5	1.0	1.5
60	1:720	0.6	1.2	1.8
100	1:1,200	1.0	2.0	3.0
200	1:2,400	2.0	4.0	6.0
400	1:4,800	4.0	8.0	12.0
500	1:6,000	5.0	10.0	15.0
800	1:9,600	8.0	16.0	24.0
1000	1:12,000	10.0	20.0	30.0
1667	1:20,000	16.7	33.3	50.0

Red = Limits of Satellite Imagery. Blue = Limits of Aerial Photography.
Green = Ground Survey Methods required.

Coordinate System

The U.S. Army Corps of Engineers' Photogrammetric Mapping, Engineer Manual states that the most commonly encountered map projections in engineering surveying and mapping are the State Plane Coordinate Systems (SPCS) and the Universal Transverse Mercator (UTM). State Plane Coordinate Systems are defined for both the NAD 27 and NAD 83 datum. For the NAD 27 SPCS definition, the unit of length is the US Survey Foot. For NAD 83 SPCS definition, the unit of length is variable among the states. Care must be exercised when using NAD 83 SPCS values in feet since either US Survey Foot or International Foot may be used in a specific state of locality.

The UTM projection is also commonly used in the military. UTM uses a scale factor of 1/2500 (0.9996 = 1/2500) to reduce the number of UTM zones for the entire world to 60. In 1930, the U.S. National Geodetic Survey developed the State Plane Coordinate System (SPCS) to increase the coordinate system accuracy for civil use. The SPCS uses a scale factor of 1/10,000. Measured distances on the ground more closely correspond to grid distances with a Grid System judiciously designed for civil use (Mugnier, 1998). The SPCS is

the recommended coordinate system for installation maps within the Continental United States (CONUS).

Aerial Photography Parameters

Flight height for aerial photography acquisition is usually given as an average above ground elevation and planned in accordance with the desired accuracy specifications for the intended mapping. For most installation mapping activities aerial cameras with a 6” focal length are employed. Table 3-2, Arial Photography Acquisition Parameters, displays parameters needed to obtain mapping specifications indicated in this guide.

Table 3-2: Aerial Photography Acquisition Parameters

Photo Scale Range	Altitude (meters)	Altitude (feet)	Map Scale Range	Map Scale 1"=x'	Contour Interval (meters)	Contour Interval (feet)	Typical Use
1:2400 - 1:3000	450	1500	1:480 - 1:500	1"=40'	0.4	1.5	Site map
1:3000 - 1:4000	600	2000	1:600	1"=50'	0.5	1.5	Small Area Development Map Utility Maps
1:4000 - 1:5000	760	2500	1:1200	1"=100'	1	3	Area Development Map Special Area Maps - Airfields, Ports, Harbors etc.
1:5000 - 1:12000	900	3000	1:2400	1"=200'	2	6	Cantonment Area Map Land Use Map
1:12000- 1:24000	1060	3500	1:4800	1"=400'	5	16	Environmental Concern Area Transportation Access Map
1:24000 - 1:25000	1200	4000	1:6000	1"=500'	5	16	Installation Layout Map
1:25000 - 1:26000	1350	4500	1:9600	1"=800'	5	16	Special Study - Environmental Change Map
1:26000 - 1:72000	1520	5000	1:12000	1"=1000'	5	16	Vicinity Map
			1:24000	1"=2000'	5	16	Regional Map

The following paragraphs identify typical parameters for aerial photography:

Aerial film negatives that have a departure from the specified scale of more than 5% due to tilt or flight height variations are normally unacceptable. Flight height variation of the actual height exceeding the specifications by, for example, 2% low or 5% high may be grounds for

rejection of the aerial photography. Cloud cover greater than 5% in a single image is unacceptable.

To support stereocompilation, end-lap for the aerial photography is usually specified at 60% with a permissible variation of no more than +/- 5%. Lateral side-lap is normally 30% with a permissible variation of no more than +/- 10%. Absolute crab (displacement of the principal point in a photography) exceeding 5-10° between two or more photos is usually cause for rejection. Average crab for a flight line should not exceed 3-5 degrees.

Tilt specifications are given for frames (i.e., no more than 4°). Also specified is the average tilt for a series of consecutive photos (i.e., no more than 2° for any specified count of consecutive photos), as an average for the entire project (i.e., no more than 1°), and relative tilt between consecutive photographs (i.e., no more than 6°). The particular requirements for the aerial mission may modify one or more of these parameters, but these are useful guidelines for specifying the aerial photography requirement.

Map Production Process and GIS Development Strategy

Map tasking may ultimately result in the preparation of a land base used for a geographic information system. While map tasking does not necessarily require implementation of a GIS, those individuals involved in tasking must have an awareness of the importance of the preparation of mapping that ultimately serves a GIS enterprise-wide approach. When utilizing aerial photography and photogrammetric techniques it is important to understand the primary processes associated with the performance of installation map tasking.

The steps involved in the preparation of topographic map tasking using photogrammetric techniques (photo-mapping) and associated with the development of installation maps are provided below (Nale). There are slight variations in techniques when airborne GPS is used in lieu of traditional ground control surveys; in general however, the tasks below are required with most photogrammetric mapping projects. Other sections of this report provide more information on the specific requirements associated with the significant tasks.

(1) Specify the area to be mapped, the desired map scale(s), contour interval and accuracy necessary for the map tasking (refer to Table 2-1).

(2) Determine the aerial photography parameters such as flight height, photo scale, use of ground control surveys or airborne GPS for photo control and type of film.

(3) Prepare the flight line map to be used for flying the mission to acquire the aerial photography.

(4) Plan locations and place targets for aerial photography control purposes and mark/paint utilities or structures (optional) in preparation of installation over flight.

(5) Acquire photography, process film, perform quality control and produce contact prints and diapositives.

(6) Produce photographic indexes.

(7) Perform field surveys to establish the control for mapping.

(8) Perform survey adjustments and deliver survey report for approval.

(9) Mark (drill) and measure diapositives in preparation of aerotriangulation, perform analytical aerotriangulation and deliver aerotriangulation report for approval.

(10) Perform stereocompilation (inclusive of digital elevation and terrain models) or the generation of orthophoto maps inclusive of quality control.

(11) Generate final photogrammetric map products. Include the preparation of the data with the topological structures necessary for GIS compliant data and apply TSSDS specifications.

(12) Convert other records to add thematic data sets not developed from the photogrammetric data (map tasking) and add other attribute data associated with the map tasking or thematic data sets. This process may include the scanning and digitizing of ancillary maps or other sources of data. These data are referenced to the new mapping. Apply necessary topological structures and TSSDS specifications to the data.

(13) Deliver mapping data to the installation and include meta data.

Figure 2-2 shows the summary of the photo-mapping production flow as presented in U.S. Army Corps of Engineers Photogrammetric Mapping engineer manual (EM 110-1-1000).

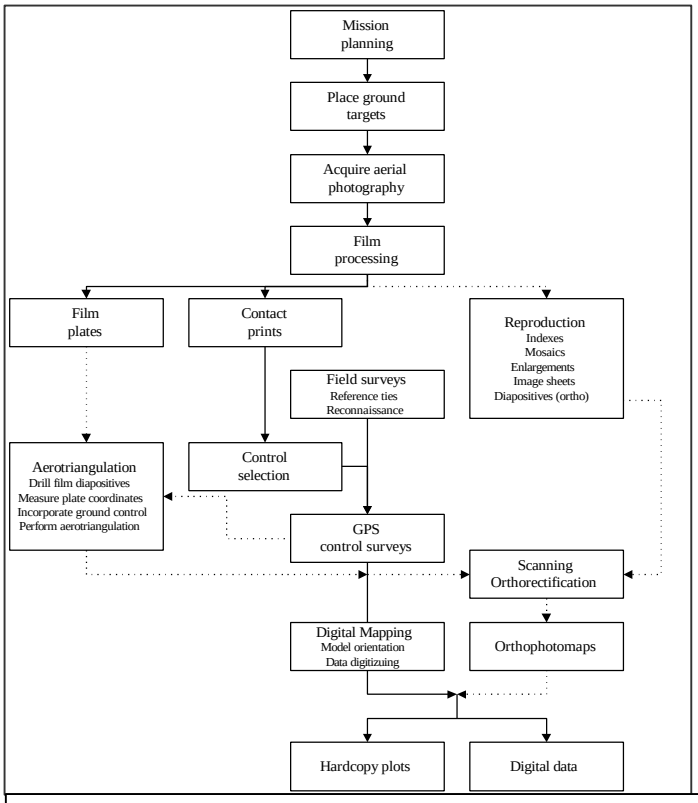


Figure 2-2. Photomapping production flow diagram

4 Conclusions and Recommendations

The best relevant guidance for installation mapping identified by the authors during the literature review are contained in the U.S. Army Corps of Engineers Photogrammetric Mapping (EM 1110-1-1000) and the Air Force Master Statement of Work for Comprehensive Planning. The EM 110-1-1000 provides a thorough discussion of the technical requirements for mapping, but is not produced specifically to address the maps required for DoD installations. The Air Force Master Statement of Work provides a comprehensive listing of installation mapping requirements. This list was modified to meet the expanded needs of the Department of Defense and each of the individual armed services.

Appendix B of this report provides guidance on the recommended maps, level of detail, accuracy and relationship to the TSSDS. Appendix D provides a sample Statement of Work (SOW) to obtain the necessary contractual support needed to develop installation maps. Each of the individual military services has agreed to prepare an addendum to this guide. The addendum will supplement the guidance provided and will specify additional mapping requirements unique to the individual service. The service supplement, coupled with this document, will provide the necessary guidance for each installation to determine their mapping needs.

This study was a first step in a process to consolidate guidance for DoD map tasking. Continuation of this research through a cooperative effort with representatives from each of the services to develop common guidance will prove extremely beneficial. The resulting guidance will serve the interests of the Center and reduce the complexity and costs for obtaining reliable map and geospatial data from military installations.

Glossary

The following glossary was extracted from the large-scale Mapping Guidelines published by the U.S. Geological Survey.

Accuracy - Accuracy is the degree of conformity with a standard. Accuracy relates to the quality of a result and is distinguished from precision, which relates to the quality of the operation by which the result is obtained.

Aerotriangulation (or bridging) - The process of developing a network of horizontal and (or) vertical positions from a group of known positions utilizing direct or indirect measurements from aerial photographs and mathematical computations.

Bench mark - Relatively permanent material object, natural or artificial, bearing a marked point whose elevation above or below an adopted datum is known.

Cartography - Science and art of making maps and charts. The term may be taken broadly as comprising all the steps needed to produce a map: planning, aerial photography, field surveys, photogrammetry, editing, color separation, and multicolor printing.

Compilation - Preparation of a new or revised map or chart, or portion thereof, from existing maps, aerial photographs, field surveys, and other sources.

Contour - Imaginary line on the ground, all points of which are the same elevation above or below a specified datum.

Contour interval - Contour interval is the difference in elevation between two adjacent contours.

Control, mapping - Points of established position or elevation, or both, which are used as fixed references in positioning and correlating map features. Fundamental control is provided by stations in the national networks of triangulation and traverse (horizontal control) and leveling (vertical control). Usually it is necessary to extend geodetic survey, based on the fundamental stations, over the area to be mapped, to provide a suitable density and distribution of control points.

Control station - Point on the ground whose position (horizontal or vertical) is known and can be used as a base for additional survey work.

Coordinates, origin of - A defined point in a system of coordinates which serves as a reference point from which the system coordinates are measured.

Coordinates, origin of - Point in a system of coordinates which serves as a zero point in computing the systems elements or in prescribing its use.

Crab (aerial photography) - The condition caused by failure to orient the camera with respect to the track of the airplane. In vertical photography, crab is indicated by the edges of the photographs not being parallel to the intended ground track of the aircraft.

Culture - Features constructed by man that are under, on, or above the ground which are delineated on a map. These include roads, trails, buildings, canals, and sewer system. In a broad sense, the term also applies to all names, other identification, and legends on a map.

Datum (P1. datums) - In surveying, a reference system for computing or correlating the results of surveys. There are two principal types of datums: vertical and horizontal. A vertical datum is a level surface to which heights are referred. In the United States, the generally adopted vertical datum for leveling operations is the National Geodetic Vertical Datum of 1929. The horizontal datum, used as a reference for position, is defined by the latitude and longitude of an initial point, the direction of a line between this point and a specified second point, and two dimensions which define the spheroid.

Datum, national geodetic vertical - See National Geodetic Vertical Datum of 1929.

Displacement - Any shift in the position of an image on a photograph due to tilt during photography, scale changes in the photographs, and relief of the area photographed.

Elevation - Vertical distance of a point above or below a reference surface or datum.

Focal length - A general term for the distance between the rear node of a lens and the point where the image of an infinitely distant object comes into critical focus.

Geodesy - Science concerned with the measurement and mathematical description of the size and shape of the Earth and its gravitational field. Geodesy also includes the large-scale extended surveys for determining positions and elevations of points in which the size and shape of the Earth must be taken into account.

Graticule - Network of parallels and meridians on a map or chart.

Grid- Network of uniformly spaced parallel straight lines intersecting at right angles. When superimposed on a map, it usually carries the name of the projection used for the map-that is, Lambert grid, transverse Mercator grid, universal transverse Mercator grid. However, care must be taken not to confuse a projection grid with the underlying network of geographic meridians and parallels generated by the projection.

Imagery - Visible representation of objects and (or) phenomena as sensed or detected by cameras, infrared and multispectral scanners, radar, and photometers. Recording may be on photographic emulsion (directly as in a camera or indirectly after being first recorded on magnetic tape as an electrical signal) or on magnetic tape for subsequent conversion and display on a cathode ray tube.

Latitude - Angular distance, in degrees, minutes, and seconds, of a point north or south of the equator.

Lens distortion - Lens aberrations shifting the position of images off the axis in which objects at different angular distances from the axis undergo different magnifications.

Longitude - Angular distance, in degrees, minutes, and seconds, of a point east or west of the Greenwich meridian.

Map - Graphic representation of the physical features (natural, artificial, or both) of a part of the whole of the Earth's surface, by means of signs and symbols or photographic imagery, at an established scale, on a specified projection, and with the means of orientation indicated.

Map, engineering - Map showing information that is essential for planning an engineering project or development and for estimating its cost. It usually is a large-scale map of a small area or of a route. It may be entirely the product of an engineering survey, or reliable information may be collected from various sources for the purpose and assembled on a base map.

Map, line - Map composed of lines and other symbols as distinguished from imagery maps.

Map, planimetric - Map that presents only the horizontal positions for features represented; distinguished from a topographic map by the omission of relief in measurable form. The features usually shown on a planimetric map include rivers, lakes, and seas; mountains, valleys, and plains; forest and prairies; cities, farms, transportation routes, and public utility facilities; and political and private boundary lines. A planimetric map intended for special use may present only those features essential to the purpose to be served.

Map, topographic - Map that presents the horizontal and vertical positions of the features represented; distinguished from a planimetric map by the addition of relief in measurable form.

Map projection - Systematic representation of all or part of the surface of a round body, especially the Earth, on a plane. This usually includes lines delineating meridians and parallels.

Map series - Family of maps conforming generally to the same specifications and designed to cover an area or a country in systematic pattern.

Meridian - Great circle on the surface or the Earth passing through the geographical poles and any given point on the Earth's surface. All points on a given meridian have the same longitude.

Metric system - Decimal system of weights and measures based on the meter as a unit length and the kilogram as a unit mass.

Monument (surveying) - Permanent physical structure marking the location of a survey point. Common types of monuments are inscribed metal tablets set in concrete posts, solid rock, or part of buildings; distinctive stone posts; and metal rods driven in the ground.

Neatline - Line separating the body of a map from the map margin. On a standard U.S. Geological Survey quadrangle map, the neat lines are the meridians and parallels delimiting the quadrangle.

Origin of coordinates - Point in a system of coordinates that serves as a zero point in computing the system's elements or in prescribing its use.

Orthophotograph - A photograph having the properties of an orthographic projection. It is derived from a conventional perspective photography by simple or differential rectification so that image displacements and scale differences caused by camera tilt and terrain relief are removed.

Orthophotographic map - Map produced by assembling orthophotographs at a specified uniform scale in a map format.

Orthophoto map - An orthophotographic map with contours and cartographic treatment, presented in a standard format, and related to standard reference systems.

Orthophoto mosaic - Assembly of orthophotographs forming a uniform-scale mosaic.

Overlap - The amount, by which one photograph overlaps another, customarily expressed as a percentage. The overlap between aerial photographs in the same flightline is called the endlap, and the overlap between photographs in adjacent parallel flightlines is called the sidelap.

Overlay - Printing or drawing on a transparent or translucent medium intended to be placed in register on a map or other graphic which depicts information which does not appear on the base material or which requires special emphases.

Parallel - A circle on the figure of the Earth formed by the intersection of the Earth's figure with a plane parallel to the plane of the Equator. This line is identified by its latitude. The equator is also a parallel.

Pass point - A point whose horizontal and (or) vertical position is determined from photographs by photogrammetric methods and which is intended for use as a control point in the orientation of the photographs.

Photogrammetry - The science or art of obtaining reliable measurements or information from photographs or other sensing systems.

Photo-index - An assembly of photographs in their proper relative positions, generally annotated and copied at a reduced scale.

Photo-map (photographic map) - Map made by adding marginal information, descriptive data, and a reference system to a photograph or assembly of photographs.

Public land survey system - Public lands are subdivided by a rectangular system of surveys established and regulated by the Bureau of Land Management. The standard format for subdivision is by townships measuring 6 miles (480 chains) on a side. Townships are further subdivided into 36 numbered sections of 1 square mile (640 acres) each.

Quadrangle - Four-sided area bounded by parallels of latitude and meridians of longitude used as an area unit in mapping (dimensions are not necessarily the same in both directions).

Relief - Elevation variations of the land or sea bottom.

Scale - Relationship existing between a distance on a map, chart, or photograph and the corresponding distance on the Earth.

Spot elevation - Point on a map or chart whose height above a specified datum is noted, usually by a dot or a small sawbuck and elevation value. Elevations are shown, on a selective basis, for road forks and intersections, grade crossings, summits of hills, mountains and mountain passes, water surfaces of lakes and ponds, stream forks, bottom elevations in depressions, and large flat areas.

State plane coordinate system - Rectangular coordinate systems established beginning in the 1930's by the U.S. Coast and Geodetic Survey, providing one or more zones for each State based on a specific map projection and origin for each zone.

Stereocompilation - Production of a map or chart manuscript from aerial photographs and geodetic control data by means of photogrammetric instruments.

Stereoplotter - Instrument for plotting a map by observation of stereo-models formed by pairs of photographs.

Target - The distinctive marking or instrumentation of a ground point to aid in its identification on a photograph. A target is so arranged and placed as to form a distinctive image over a geodetic or other control-point marker, on a property corner or line, or at the position of an identifying point above an underground facility or feature.

Topography - Configuration (relief) of the land surface; the graphic delineation or portrayal of that configuration in map form, as by contour lines; in oceanography the term is applied to a surface such as the sea bottom or a surface of given characteristics within the water mass.

Triangulation - Method of extending horizontal position on the surface of the Earth by measuring the angles of triangles and the included sides of selected triangles.

Universal Transverse Mercator (UTM) grid - Rectangular coordinate system based on the UTM projection, a specific form of the Transverse Mercator Projection which consists (basically) of 6 -wide zones of longitude extending from latitudes 84º N. And 80º S.

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Appendix A
TSSDS Map Name Prefix Schema

Appendix A
TSSDS Entity Classes

TSSDS ENTITY CLASSES				
ENTITY CLASS NAME	ENTITY SET NAME	ENTITY CLASS ABBREVIATION	MAP PREFIX	DEFINITION
auditory_noise	auditory	noi	aunoi	The generation, detection, and sampling of noise or other sound effects.
auditory_management	auditory	mgt	aumgt	Actions or objects intended to control or mitigate the effects of noise production.
boundary_jurisdiction	boundary	jur	bdjur	Geographical areas divided for political, jurisdictional, economic, and representational purposes.
boundary_economic	boundary	eco	bdeco	Boundaries or areas where economic control, authority, customs, or trade regulation are in effect.
boundary_public_safety	boundary	pub	bdpub	Relating to the control of areas defined for public safety issues such as fire, rescue, or police.
buildings_general	buildings	gen	bggen	Man-made structures located on the face of the earth that were created to protect man and his possessions from the environment; or to enhance man's activities.
cadastre_real_estate	cadastre	rel	cdrel	Areas representing specific ownership or zoning issues of property.
cadastre_dod_property	cadastre	dod	cddod	The property owned by or being used by the United States Department of Defense.
cadastre_plss	cadastre	pls	cdpls	Information relating to the United States Public Land Surveying System.
climate_general	climate	gen	clgen	The general state of the atmosphere that surrounds the earth and instruments and observations that monitor it.
climate_temperature	climate	tmp	cltmp	The thermal state of the atmosphere that surrounds the earth.
climate_precipitation	climate	pcp	clpcp	The characteristics which are represented by various forms of water which fall upon the surface of the earth.
common_general	common	gen	cmgen	The description of components of data that are common to all entity sets, entity classes, entity types, entities, and attribute tables.
common_metadata	common	met	cmmet	The information that describes a data set or subsets. Metadata can describe a set of data as large as an entire installation or as small as an individual building.

TSSDS ENTITY CLASSES				
ENTITY CLASS NAME	ENTITY SET NAME	ENTITY CLASS ABBREVIATION	MAP PREFIX	DEFINITION
common_dictionary	common	dic	cmdic	The dictionary description of entity set, entity class, entity type, entity, attribute table, attribute, and domain database components.
common_grid	common	grd	cmgrd	Regular patterns of horizontal and vertical lines used to represent regular and irregular coordinate intervals along the x and y axis. Grids can be used to generate arbitrary reference systems which are common on gazetteer maps.
common_media	common	med	cmmed	Component digital forms of data that are associated with and are common to many graphic entities, and their descriptive attributes.
communications_general	communications	gen	cogen	Antenna and other infrastructure which support the transmission and reception of electromagnetic signals.
communications_cable_television	communications	ctv	coctv	Lines, junctions, and devices in support of cable television distribution.
communications_telephone	communications	tel	cotel	Lines, junctions, distribution control boxes, and other devices support the connections of telephone systems.
communications_microwave	communications	mic	comic	Relating to the transmission and reception of microwaves for the purpose of communication.
cultural_archeological	cultural	arc	crarc	The actions or activities to explore or further understand items of historical significance.
cultural_historic	cultural	hst	crhst	The areas or structures which have relevance to the past.
cultural_management	cultural	mgt	crmgt	The actions taken to assist or control cultural resources.
cultural_general	cultural	gen	crgen	The actions or activities to explore or further understand items of historical significance.
env_haz_bldg_hazard_remediation	environmental_hazards	bdh	ehbdh	Activities involving the evaluation, investigation, study, treatment, reduction, or removal of items, materials, or conditions associated with buildings and structures which pose an environmental hazard.
env_haz_pollution_remediation	environmental_hazards	rem	ehrem	Activities involving the treatment, reduction, or removal of environmental hazards.
env_haz_solid_waste_management	environmental_hazards	swm	ehswm	Management of solid, semi-solid, liquid, or containerized gaseous wastes that are discarded and may or may not be hazardous.
env_haz_munmat_munwaste_manage	environmental_hazards	mmw	ehmmw	Management of contained and bulk chemical compounds, mixtures, and devices whose primary purpose is to function by detonation or deflagration with instantaneous release of heat and gases.

TSSDS ENTITY CLASSES				
ENTITY CLASS NAME	ENTITY SET NAME	ENTITY CLASS ABBREVIATION	MAP PREFIX	DEFINITION
env_haz_hazmat_hazwaste_manage	environmental_hazards	hmw	ehhmw	Management of contained and bulk products or substances which serve a useful purpose (materials), and products which no longer serve a useful purpose (waste), which, without proper precautions may be hazardous to the environment.
env_haz_characterization	environmental_hazards	cha	ehcha	Activities, processes, and equipment involved in collecting and analyzing a representative part of a larger item for the purpose of determining, or showing, evidence of quality or composition.
env_haz_site_management	environmental_hazards	sit	ehsit	Site management information concerning a site where environmental hazards are, or may be, located.
env_haz_emergency_preparedness	environmental_hazards	emp	ehemp	Items or features maintained and available for use in responding to environmental hazard type emergencies and spills.
env_haz_munitions_remediation	environmental_hazards	mrm	ehmrm	Activities involving the evaluation, investigation, study, treatment, reduction, or removal of munitions hazards.
env_haz_general	environmental_hazards	gen	ehgen	Miscellaneous information and items associated with a site where environmental hazards are, or may be located.
env_haz_air_pollution	environmental_hazards	air	ehair	Activities involving the evaluation, investigation, and study of natural and man-made substances, materials, and conditions in the air which are, or have the potential to be, detrimental to life and ecosystems on the earth.
env_haz_soil_pollution	environmental_hazards	soi	ehsoi	Activities involving the evaluation, investigation, and study of natural and man-made substances, materials, and conditions in the soil which are, or have the potential to be, detrimental to life and ecosystems on the earth.
env_haz_groundwater_pollution	environmental_hazards	gwt	ehgwt	Activities involving the evaluation, investigation, and study of natural and man-made substances, materials, and conditions in the groundwater which are, or have the potential to be, detrimental to life and ecosystems on the earth.
env_haz_surface_water_pollution	environmental_hazards	swt	ehswt	Activities involving the evaluation, investigation, and study of natural and man-made substances, materials, and conditions in the surface water which are, or have the potential to be, detrimental to life and ecosystems on the earth.

TSSDS ENTITY CLASSES				
ENTITY CLASS NAME	ENTITY SET NAME	ENTITY CLASS ABBREVIATION	MAP PREFIX	DEFINITION
env_haz_sediment_pollution	environmental_hazards	sed	ehsed	Activities involving the evaluation, investigation, and study of natural and man-made substances, materials, and conditions in the sediment which are, or have the potential to be, detrimental to life and ecosystems on the earth.
env_haz_general_pollution	environmental_hazards	pol	ehpol	Activities involving the evaluation, investigation, and study of natural and man-made substances, materials, and conditions affecting more than one matrix which are, or have the potential to be, detrimental to life and ecosystems on the earth.
env_haz_regulated_tank_manage	environmental_hazards	tnk	ehtnk	Management of storage tanks which are subject to compliance with environmental regulations.
fauna_management	fauna	mgt	famgt	The actions taken to assist or control animal life.
fauna_habitat	fauna	hab	fahab	The areas where animal life exists or thrives fauna. This class is included to represent the aggregate fauna population. For specific species management, use the appropriate family Entity Class.
fauna_general	fauna	gen	fagen	The areas where animal life exists or thrives.
fauna_amphibia	fauna	amp	faamp	Specific species management documentation relating to amphibia fauna. This class was designed to be used to document ranges, habitats, and sites of individual amphibia species.
fauna_aves	fauna	ave	faave	Specific species management documentation relating to aves fauna. This class was designed to be used to document ranges, habitats, and sites of individual aves species.
fauna_crustacea	fauna	cru	facru	Specific species management documentation relating to crustacea fauna. This class was designed to be used to document ranges, habitats, and sites of individual crutacea species.
fauna_insecta	fauna	ins	fains	Specific species management documentation relating to insecta fauna. This class was designed to be used to document ranges, habitats, and sites of individual insecta species.
fauna_mammalia	fauna	mam	famam	Specific species management documentation relating to mammila fauna. This class was designed to be used to document ranges, habitats, and sites of individual mammilia species.

TSSDS ENTITY CLASSES				
ENTITY CLASS NAME	ENTITY SET NAME	ENTITY CLASS ABBREVIATION	MAP PREFIX	DEFINITION
fauna_mollusca	fauna	mol	famol	Specific species management documentation relating to mollusca fauna. This class was designed to be used to document ranges, habitats, and sites of individual mollusca species.
fauna_pisces	fauna	pis	fapis	Specific species management documentation relating to pisces fauna. This class was designed to be used to document ranges, habitats, and sites of individual pisces species.
fauna_reptilia	fauna	rep	farep	Specific species management documentation relating to reptilia fauna. This class was designed to be used to document ranges, habitats, and sites of individual reptilia species.
flora_management	flora	mgt	flmgt	Human activities designed to assist or control plant life.
flora_habitat	flora	hab	flhab	The areas where plant life exists or thrives. This class is included to represent the aggregate flora population. For specific species management, use the appropriate family Entity Class.
flora_general	flora	gen	flgen	The actions taken to assist or control plant life.
flora_tree	flora	tre	fltre	Specific species management documentation relating to trees. This class was designed to be used to document ranges, habitats, and sites of individual tree species.
flora_shrub	flora	shr	flshr	Specific species management documentation relating to shrubs. This class was designed to be used to document ranges, habitats, and sites of individual shrub species.
flora_liana	flora	lia	fllia	Specific species management documentation relating to liana. This class was designed to be used to document ranges, habitats, and sites of individual liana species.
flora_herb	flora	hrb	flhrb	Specific species management documentation relating to herbs. This class was designed to be used to document ranges, habitats, and sites of individual herb species.
flora_bryoid	flora	bry	flbry	Specific species management documentation relating to bryoid. This class was designed to be used to document ranges, habitats, and sites of individual bryoid species.
flora_epiphyte	flora	epi	flepi	Specific species management documentation relating to epiphyte. This class was designed to be used to document ranges, habitats, and sites of individual epiphyte species.

TSSDS ENTITY CLASSES

ENTITY CLASS NAME	ENTITY SET NAME	ENTITY CLASS ABBREVIATION	MAP PREFIX	DEFINITION
flora_thallophyte	flora	thl	flthl	Specific species management documentation relating to thallophyte. This class was designed to be used to document ranges, habitats, and sites of individual thallophyte species.
flora_preservation	flora	prz	flprz	Specific preservation activities that are intended to protect and preserve the natural environment.
geodetic_survey	geodetic	srv	gdsrv	Specific recording or documenting the locations on the surface of the earth
geodetic_usgs	geodetic	sgs	gdsgs	Data relating to surveying and mapping by the United States Geological Survey under the Department of the Interior.
geology_lithology	geology	lth	gelth	The science dealing with the physical characteristics of rock; i.e. color, mineral composition and grain size.
geology_tectonic	geology	tec	getec	The geologic formations or activities which relate to the movement of the earth's plates.
geology_surface	geology	sur	gesur	The geologic formations or activities which exist at the surface of the earth.
geology_subsurface	geology	sub	gesub	The geologic formations or activities which exist below the surface of the earth.
hydrography_wetland	hydrography	wet	hywet	Transitional lands between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. The soils are predominantly saturated with water and the plants and animals that live there are specialized for this ecosystem.
hydrography_coastal_zone	hydrography	czn	hyczn	The transition zone where the land meets the water, the region that is directly influenced by marine and lacustrine hydrodynamic processes. Extends offshore to the continental shelf break and onshore to the first major change in topography above the reach of major storm waves.
hydrography_hydrobasin	hydrography	hdb	hyhdb	The areas on the surface of the earth where rain water is likely to collect.
hydrography_floodplain	hydrography	flp	hyflp	Lowland and relatively flat areas adjoining inland and coastal waters including flood prone areas of offshore islands. FEMA has categorized floodplains into 100-year (1% change of flooding in a year) and 500-year (0.2% chance of flooding in a year) zones.
hydrography_subsurface	hydrography	sub	hysub	The scientific description and analysis of the physical conditions, boundaries, flow, and related characteristics of earth's subsurface fresh waters.

TSSDS ENTITY CLASSES				
ENTITY CLASS NAME	ENTITY SET NAME	ENTITY CLASS ABBREVIATION	MAP PREFIX	DEFINITION
hydrography_surface	hydrography	sur	hysur	The scientific description and analysis of the physical conditions, boundaries, flow, and related characteristics of earth's surface waters
hydrography_ice_and_snow	hydrography	ice	hyice	The areas on the surface of the Earth perennially covered by ice or snow.
hydrography_management	hydrography	mgt	hymgt	Areas designated to assist in the storage and management of rainwater.
improvement_outdoor_recreation	improvement	rec	imrec	Areas of land or features designated for individual or group use for recreation or leisure.
improvement_flood_control	improvement	fdc	imfdc	Man-made features designed to control excessive rainfall and/or restrict the flow of watercourses, and the extent of water bodies.
improvement_general	improvement	gen	imgen	Man-made features having a generic or multiple purpose.
improvement_machinery	improvement	mac	immac	Large equipment or apparatus used for movement of material/personnel, or other miscellaneous machinery.
improvement_erosion_control	improvement	ero	imero	Man-made features designed to limit the effect of waves and currents along the banks of watercourses and water bodies.
improvement_wells	improvement	wel	imwel	Relating to holes drilled or dug into the ground for the purpose of removing or injecting liquids or gases, or for monitoring ground conditions.
improvement_athletic_recreation	improvement	ath	imath	Improved areas of land or features designated for individual or group use for sports or athletic events.
land_status_land_management	land_status	mgt	lsmgt	Areas of land controlled or designated for specific purposes or uses.
land_status_land_condition	land_status	cnd	lscnd	Areas of land specified as their use or condition.
land_status_general	land_status	gen	lsgen	Areas of land where specific status is affected by the use of land.
landform_topography	landform	top	lftop	The relative position of the natural, physical features of a place or region that describes the configuration
landform_hypsography	landform	hyp	lfhyp	The science dealing with the elevation of an area above some known reference or datum, such as mean sea level.
landform_bathymetry	landform	bth	lfbth	The science of measuring and charting the depth of seas, lakes, and other bodies of water and the bottom structures of those waters.
military_security	military_operations	sec	mlsec	Control of access to sensitive military operations, training, materials, or equipment.

TSSDS ENTITY CLASSES				
ENTITY CLASS NAME	ENTITY SET NAME	ENTITY CLASS ABBREVIATION	MAP PREFIX	DEFINITION
military_safety	military_operations	sft	mlsft	Control of the well being of military personnel or equipment during military operations.
military_training	military_operations	tng	mltng	Areas or facilities used to maintain the readiness of military personnel or equipment.
military_air_operations	military_operations	air	mlair	Operations or exercises of military aircraft and their related airspace.
military_public_relations	military_operations	gen	mlpub	The reporting or recording of accidents, incidents, or other events of interest to the general public.
olfactory_general	olfactory	gen	olgen	General information regarding odors in the atmosphere.
soil_general	soil	gen	sogen	The general characteristics of the unconsolidated materials above bedrock.
transportation_airfield_facility	transportation	afl	trafl	The infrastructure necessary to support airfields.
transportation_air	transportation	air	trair	Relating to movement through the air or air traffic.
transportation_railroad	transportation	rrd	trrrd	Relating to movement of individuals or freight over rails.
transportation_vehicle	transportation	veh	trveh	Relating to movement of automobiles, trucks, or other vehicles.
transportation_pedestrian	transportation	ped	trped	Relating to movement of individuals or individual traffic.
transportation_marine	transportation	mar	trmar	Relating to the movement of ships and other large vessels from one location to another.
transportation_marine_navigation	transportation	nav	trnav	Relating to nautical navigation aids, the marking of shipping lanes and channels, as well as hazards to marine navigation.
transportation_ports_and_harbors	transportation	hrb	trhrb	Relating to marine terminals, ports, harbors, and other locations where passengers and cargo are transferred to and from ships in protected waters.
transportation_general	transportation	gen	trgen	Relating to transportation features which are used in support of a variety of transportation functions or which are under construction and not yet in use.
transportation_lock_system	transportation	loc	trloc	The movement of ships, boats, barges, and tugs from one water level to another.
utilities_cntrl_mntr_system	utilities	ecm	utecm	The components of an electronic monitoring and control (emcs) system including cables, devices, etc.
utilities_electrical_system	utilities	ele	utele	The components of an electrical distribution system including cables, switches, devices, motors, transformers, etc.
utilities_fuel_system	utilities	ful	utful	The components of a fuel distribution system consisting of pipes, fittings, fixtures, pumps, tanks, etc.

TSSDS ENTITY CLASSES				
ENTITY CLASS NAME	ENTITY SET NAME	ENTITY CLASS ABBREVIATION	MAP PREFIX	DEFINITION
utilities_general	utilities	gen	utgen	The components of a utility system which are universal in use and purpose and do not belong to a specific utility.
utilities_industrial_system	utilities	inw	utinw	The components of an industrial waste collection system including pipes, fittings, fixtures, tanks, lagoons, etc.
utilities_natural_gas_system	utilities	gas	utgas	The components of a natural gas distribution system consisting of pipes, fittings, fixtures, etc.
utilities_storm_system	utilities	sto	utsto	The components of a storm drainage collection system including pipes, fittings, fixtures, etc.
utilities_wastewater_system	utilities	wwt	utwwt	The components of a wastewater collection system including pipes, fittings, fixtures, treatment plants, collection locations, etc.
utilities_water_system	utilities	wat	utwat	The components of a water system including pipes, fittings, valves, fixtures, treatment plants, etc.
utilities_heat_cool_system	utilities	hcs	uthcs	The components of a heating and cooling distribution system consisting of pipes, fittings, fixtures, etc.
utilities_electrical_ext_light	utilities	exl	utexl	The components of an electrical exterior lighting system including cables, switches, devices, transformers, etc.
utilities_saltwater_system	utilities	swt	utswt	The components of a salt water collection system.
utilities_compressed_air_system	utilities	air	utair	The components of a compressed air system.
visual_general	visual	gen	vsgen	General information relative to material which is visible in the atmosphere.
visual_aesthetic_view	visual	aes	vsaes	Relating to the overall aesthetic value of a particular scene or view.

Appendix B
Recommended Guidelines for Map Themes and Features

Appendix C
ASPRS STANDARDS FOR LARGE SCALE MAPPING

Appendix C
ASPRS Standards for Large Scale Mapping

Map accuracies are defined by the positional accuracy of a particular graphical or spatial features depicted. A map accuracy standard classifies a map as statistically meeting a certain level of accuracy. For most new site mapping projects, the desired accuracy is stated in the specifications, usually based on the final development scale of the map--both the horizontal "target" scale and vertical relief (specified contour interval or digital elevation model). etc. Often, however, in developing engineering plans, spatial data bases may be developed from a variety of existing source data products, each with differing accuracies--e.g., mixing 1 in = 60 ft topo plans with 1 in = 400 ft reconnaissance topographical mapping. Defining an "accuracy standard" for such a mixed databases is difficult and requires retention of the source of each data feature in the base. In such cases the developer must estimate the accuracy of the mapped features.

a. ASPRS Standard. For new site mapping work, there are a number of industry and Federal mapping standards that may be used in specifications. The recommended standard for facility engineering is the ASPRS "Accuracy Standards for Large-Scale Maps" (ASPRS 1990). This standard, like most other mapping standards, defines map accuracy by comparing the mapped location of selected well-defined points to their "true" location, as determined by a more accurate, independent field survey. Alternately, when no independent check is feasible or practicable, a map's accuracy may be estimated based on the accuracy of the technique used to locate mapped features--e.g., photogrammetry, GPS, total station, plane table, The ASPRS standard has application to different types of mapping, ranging from wide-area, small-scale, GIS mapping to large-scale construction site plans. It is applicable to all types of horizontal and vertical geospatial mapping derived from conventional topographic surveying or photogrammetric surveys. This standard should be specified for detailed construction site plans that are developed using conventional ground topographic surveying techniques (i.e., electronic total stations, plane tables, kinematic DGPS). The ASPRS standard is especially applicable to site plan development work involving mapping scales larger than 1:20,000 (1 in. = 1,667 ft); it therefore applies to the more typical map scales in the 1:240 (1 in. = 20 ft) to 1:4,8000 (1 in. = 400 ft) range. Its primary advantage over other standards is that it contains more definitive statistical map testing criteria, which, from a contract administration standpoint, is desirable. Using the guidance in Tables 1 and 2, specifications for site plans need only indicate the ASPRS map class, target scale, and contour interval.

b. Horizontal (planimetric) accuracy criteria. The ASPRS planimetric standard compares the root mean square error (RMSE) of the average of the squared discrepancies, or differences in coordinate values between the map and an independent topographic ground survey of higher accuracy (i.e., check survey). The "limiting RMSE" is defined in terms of meters (feet) at the ground scale rather than in millimeters (inches) at the target map scale. This results in a linear relationship between RMSE and target map scale; as map scale decreases, the RMSE increases linearly. The RMSE is the cumulative result of all errors including those introduced by the processes of ground control surveys, map compilation, and final extraction of ground dimensions from the target map. The limiting RMSE's shown in Table 1 are the maximum permissible RMSE's established by the ASPRS standard. These limits of accuracy apply to well-defined map test points only.

c. Vertical (topographic) accuracy criteria. Vertical accuracy has traditionally been, and currently still is, defined relative to the required contour interval for a map. In cases where digital elevation models (DEM) are being generated, an equivalent contour interval can be specified, based on the required digital point-spot-elevation accuracy. The contours themselves may be later generated from a DEM using computer software routines. The ASPRS vertical standard also uses the RMSE statistic, but only for well-defined features between contours containing interpretative elevations, or spot elevation points. The limiting RMSE for Class 1 contours is one-third of the contour interval. Testing for vertical map compliance is also performed by independent, equal, or higher accuracy ground survey methods, such as differential leveling. Table 2 summarizes the limiting vertical RMSE for well-defined points, as checked by independent surveys at the full (ground) scale of the map.

Table 1a

ASPRS Planimetric Feature Coordinate Accuracy

Requirement (Ground X or Y in Meters) for Well-Defined Points

Target Map Scale	ASPRS Limiting RMSE in X or Y (Meters)		
Ratio m/m	Class 1	Class 2	Class 3
1:50	0.0125	0.025	0.038
1:100	0.025	0.05	0.075
1:200	0.050	0.10	0.15
1:500	0.125	0.25	0.375
1:1,000	0.25	0.50	0.75
1:2,000	0.50	1.00	1.5
1:2,500	0.63	1.25	1.9
1:4,000	1.0	2.0	3.0
1:5,000	1.25	2.5	3.75
1:8,000	2.0	4.0	6.0
1:10,000	2.5	5.0	7.5
1:16,000	4.0	8.0	12.0
1:20,000	5.0	10.0	15.0

Note: ASPRS Class 1 is equivalent to FGDC National Spatial Data Accuracy Standard (1994 Draft)

Table 1b

ASPRS Planimetric Feature Coordinate Accuracy

Requirement (Ground X or Y in Feet) for Well-Defined Points

Target Map Scale		ASPRS Limiting RMSE in X or Y (Feet)		
1"= x ft	Ratio ft/ft	Class 1	Class 2	Class 3
5	1:60	0.05	0.10	0.15
10	1:120	0.10	0.20	0.30
20	1:240	0.2	0.4	0.6
30	1:360	0.3	0.6	0.9
40	1:480	0.4	0.8	1.2
50	1:600	0.5	1.0	1.5
60	1:720	0.6	1.2	1.8
100	1:1,200	1.0	2.0	3.0
200	1:2,400	2.0	4.0	6.0
400	1:4,800	4.0	8.0	12.0
500	1:6,000	5.0	10.0	15.0
800	1:9,600	8.0	16.0	24.0
1,000	1:12,000	10.0	20.0	30.0
1,667	1:20,000	16.7	33.3	50.0

Table 2a

ASPRS Topographic Elevation Accuracy

Requirement for Well-Defined Points (Meters)

	ASPRS Limiting RMSE in Meters					
				Spot or Digital		
Target	Topographic			Terrain Model		
Contour	Feature Points			Elevation Points		
Interval						
	Class	Class	Class	Class	Class	Class
Meters	1	2	3	1	2	3
0.10	0.03	0.07	0.10	0.02	0.03	0.05
0.20	0.07	0.13	0.2	0.03	0.07	0.10
0.25	0.08	0.17	0.25	0.04	0.08	0.125
0.5	0.17	0.33	0.50	0.08	0.16	0.25
1	0.33	0.66	1.0	0.17	0.33	0.5
2	0.67	1.33	2.0	0.33	0.67	1.0
4	1.33	2.67	4.0	0.67	1.33	2.0
5	1.67	3.33	5.0	0.83	1.67	2.5
10	3.33	6.67	10.0	1.67	3.33	5.0

Table 2b

ASPRS Topographic Elevation Accuracy

Requirement for Well-Defined Points (Feet)

	ASPRS Limiting RMSE in Feet					
				Spot or Digital		
Target	Topographic			Terrain Model		
Contour	Feature Points			Elevation Points		
	Interval					
	Class	Class	Class	Class	Class	Class
ft	1	2	3	1	2	3
0.5	0.17	0.33	0.50	0.08	0.16	0.25
1	0.33	0.66	1.0	0.17	0.33	0.5
2	0.67	1.33	2.0	0.33	0.67	1.0
4	1.33	2.67	4.0	0.67	1.33	2.0
5	1.67	3.33	5.0	0.83	1.67	2.5

d. Map accuracy testing and certification. Specifications and/or contract provisions should indicate the requirement or option to perform independent map testing. Map testing should be performed within a fixed time period after delivery, and if performed by contract, after proper notification to the contractor. Normally, a mapping contractor will perform these quality control tests under government quality assurance oversight. In accordance with the ASPRS standard, the horizontal and vertical accuracy of a map is checked by comparing measured coordinates or elevations from the map (at its intended target scale) with spatial values determined by a check survey of higher accuracy. The check survey should be at least twice (preferably three times) as accurate as the map feature tolerance given in the ASPRS tables, and a minimum of 20 points tested. Maps and related geospatial databases found to comply with a particular standard shall have a statement indicating that standard. The compliance statement shall refer to the data of lowest accuracy depicted on the map, or, in some instances, to specific data layers or levels. The statement shall clearly indicate the target map scale at which the map or feature layer was developed. Due to the high cost of field testing, not all deliverables will be physically tested. In such cases, the statement shall clearly indicate that the procedural mapping specifications were designed and performed to meet a certain ASPRS map classification, but that a rigid compliance test was not performed. Published maps and geospatial databases whose errors exceed those given in a standard shall indicate in their legends or metadata files that the map is not controlled and that dimensions are not to scale. This accuracy statement requirement is especially applicable to GIS databases that may be compiled from a variety of sources containing known or unknown accuracy reliability.

Appendix D
Sample Statement of Work

Appendix D
Sample Statement of Work

For

Photogrammetric Mapping

1. LOCATION OF WORK. Photogrammetric mapping and related surveying services will be performed at (_____) *(list project area, state, installation, etc.) *(A map detailing the work site is attached at Section ___ of this contract).

1.1 Photogrammetric mapping and related surveying services will be performed in connection with project _____.

2. TECHNICAL CRITERIA AND STANDARDS. The following standards are referenced in this contract. In cases of conflict between these technical specifications and any referenced technical standard, these specifications shall have precedence.

2.1. USACE EM 1110-1-1000, Photogrammetric Mapping. This reference is attached to and made part of this contract. (See Contract Section ___.)

2.2. USACE EM 1110-1-1002, Survey markers and monumentation. *(This reference is attached to and made part of this contract. (See contract Section ___.)

2.3. Tri-Service Spatial Data Standards, Release ___ on CD-ROM.

2.4. Manual of Photogrammetry, ASPRS, *(_____) Edition.

2.5. *United States National Map Accuracy Standards, US Bureau of the Budget, 17 June 1947.

2.6. *Reference Guide Outline: Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways, US Department of Transportation, Federal Highway Administration, Washington, DC, 1968.

2.7. ASPRS Accuracy Standards for Large-Scale Maps, ASPRS, March 1990.

2.8. *Standards and Specifications for Geodetic Control Networks, Federal Geodetic Control Committee (FGCC), September 1984.

2.9. *Flood Insurance Study-Guidelines and Specifications for Study Contractors, Federal Emergency Management Agency (FEMA), Federal Insurance Administration, Publication FEMA 37, March 1991.

3. WORK TO BE PERFORMED. Professional photogrammetric mapping and related surveying services to be performed under this contract are defined below. Unless otherwise indicated in this contract. Each required service shall include field-to-finish effort. All mapping work will be performed using precise photogrammetric data acquisition, mensuration, and compilation procedures, including all quality control associated with these functions. The work will be accomplished in strict accordance with the photogrammetric mapping criteria contained in the technical references (Paragraph ___ above), except as modified or amplified herein.

3.1. Purpose of Work. The work to be performed under this contract is to be used as mapping information for *(installation master planning) (Design) (construction) (operation) (Maintenance) (real estate) (regulatory enforcement) (hazardous and toxic waste site _____) (_____); including those related activities and/or engineering studies covering such pertinent details as *(reservoir capacities) (channel capacities) (damage assessment) (benefits) (project location) (design of main structure and appurtenances) (relocations) (land acquisition) (land development and management) (encroachment) (construction measurement and payment) (_____).

3.2. Use of Existing Source Material. lists of various documents such as existing installation master plans, topographic surveys, etc., will be provided by the installation. This information will be used for general reference, as a work planning tool, for locating underground utility features and as a means for checking work which is generated by the Contractor. However, in all cases where a discrepancy exists between the existing source material and Contractor's generated data, the aerial photography and the Contractor=s field verification shall be accepted as more accurate and correct.

3.3. Site Visitations for Survey and Reconnaissance: All visits to the installation including airborne reconnaissance shall be coordinated in advance with the installation point of contact listed in each delivery order. Site visits are subject to the following conditions:

3.4. The Contractor and all employees shall abide by all security regulations of the installation.

4. AIRCRAFT FLIGHT OPERATIONS AND EQUIPMENT REQUIREMENTS. Survey Clearance: The Contractor shall notify the Installation Civil Engineer=s office at least 10 working days prior to going on installation property to perform survey work. The project manager will furnish the Contractor a point of contact for the detailed coordination required between the Contractor and the installation.

4.1. Aircraft and flight crew. The aircraft furnished or utilized under this contract shall be equipped with navigation and photographic instruments and accessories necessary to satisfactorily produce the required photography. The aircraft shall be maintained in operational condition during the period of this contract, and shall conform with all governing federal aviation administration and civil aeronautics board regulations over such aircraft. The flight crew and cameraman shall have had a minimum of 400 hours experience in flying precise photogrammetric mapping missions.

4.2. Camera windows and camera mounting. When high-altitude photography is required, camera windows may be needed. Camera windows shall be mounted in vibration-damping material to avoid mechanical stress to the window. Prior to photography, any camera window used shall be checked by the calibration center to ensure that it will not adversely affect lens resolution and distortion and that it is substantially free of veins, striations, and other inhomogeneties. The camera itself shall be installed in a mounting that dampens the effects of aircraft vibration. Aircraft exhaust gases shall be vented away from camera opening.

4.3. Photography Type. The Contractor shall provide single lens vertical black and white photography at scales suitable to produce the required products. Characteristics of the photography shall be suitable for analytical aerotriangulation and standard photogrammetric mapping.

4.4. Flight Plan. The minimum area(s) to be photographed are as indicated on maps *(attached at Section ___) (which will be provided for each photographic delivery order). Given the specified photo-negative scale criteria herein, the contractor shall design the flight lines for the photography to obtain proper overlap, sidelap, and endlap to assure full stereoscopic photographic coverage, in accordance with the criteria defined in this contract *(or delivery order thereto). Generally, the flight lines shall be parallel to each other and to the longest boundary lines of the area to be photographed. For single strip

photography, the actual flight line shall not vary from the line plotted on the flight map by more than the scale of the photography expressed in feet. For example, the allowable tolerance for photography flown at scale of 1 in. equals 1000 Ft. is about 1000 Ft. The flight lines shall be submitted to the government for advance approval.

4.5. Off Installation Coverage. The coverage of aerial photography will include off installation adjacent areas as determined by the Project Manager. Coverage of satellite locatiions--such as housing sites, missile sites--which are not immediately adjacent to the boundaries 1000ft of the main installation will also be determined by the project manager.

4.6. Flight Clearance: The Contractor shall notify the project manager prior to the anticipated flight date. The Contractor shall include the time required to accomplish each mission and any alternate period that should be used to reschedule the flight. The Contracting Officer will obtain and furnish to the Contractor any required clearances from the installation for these dates. Clearances issued are subject to temporary cancellation in the event of unforeseen mission requirements.

4.7. Flight Log. For each flight day, the pilot or cameraman shall prepare a flight log containing the date, project name, aircraft used, and names of crew members. In addition, the following shall be prepared for each flight line: Altitude, camera, magazine serial number, F-Stop, shutter speed, beginning and ending exposure numbers and times, and any other comments relative to the flight conditions. These flight logs, or copies thereof, may be incorporated into the film report (if required) and will be delivered to the contracting officer as specified in this contract.

4.8. Subcontracted Photography. Before commencement of any aerial photography under this contract *(or work order) by a subcontractor, the contractor shall furnish the contracting officer, in writing, the name of such subcontractor, together with a statement as to the extent and character of the work to be done under the subcontract, including applicable camera certifications.

4.8.a. Boundaries. All of the area appearing on the first and last negative in each flight line extending over a boundary shall be outside the boundary of the project area. The principal point of two photographs on both ends of each flight line shall be taken past the boundary line of the project. Each strip of photographs along a boundary shall extend over the boundary not less than *(fifteen) (_____) (___)) percent of the width of the strip.

4.8.b. Endlap. *(unless otherwise specified in a delivery order,) the forward overlap shall be *sixty (60) percent *(+,- _____) percent. Endlap of less than *(55)) (_)) percent in one or more negatives may be cause for rejection of the negative or negatives in which such deficiency or excess of endlap occurs.

4.8.c. Sidelap. *(Unless otherwise specified in a delivery order,) the lateral sidelap shall average *(30 percent) *(+, - ten 10) (+,_____) percent. Any negative having sidelap less than *(fifteen (15) (_____) percent or more than *(50) (_____) percent may be rejected. The foregoing requirement can be varied in cases where the strip area to be mapped is slightly wider than the area that can be covered by one strip of photographs, where increase in sidelap is required for control densification purposes, or where increase or decrease in sidelap is required to reach established ground control.

4.9. Crabbing. Any series of two or more consecutive photographs, crabbed in excess of 10 degrees as measured from the mean flight path of the airplane as indicated by principal points of the consecutive photographs, may be considered cause for rejection of the photographs in the flight within 10 miles of the rejective negatives.

4.10. Tilt. The average tilt for photographs shall not exceed 1 degree and maximum tilt shall not exceed 3 degrees in a flight strip.

4.11. Suitable Conditions. All photography shall be accomplished between 0900 and 1500 hours, Standard Time Zone, when the atmosphere is sufficiently clear, and when no part of the terrain being photographed is obscured by clouds, cloud shadows, smoke, fog or snow, except with the permission of the project manager. Every effort shall be made to acquire all the photography during the same day.

4.12. Marking. The Contractor shall mark on each negative of the photography assignment the date of exposure, the approximate scale (1:xxxxxx), file number, roll number, flight line number, and exposure number. All such editing of numbered negatives shall be made by mechanical lettering, with characters 0.2 inch high, and shall be so placed as to appear within the image on the forward edge (in the line of flight) of the positive paper prints, to read from the back edge, all in relative positions as follows:

Date - Scale - File No. - Flight Line No. - Photo No.

4.13. Paper Prints. All paper prints shall be made on double weight semi-matte paper stock. They shall be sharp and clear, shall contain all highlight, and shadow detail, and shall be evenly toned. They shall be permanently fixed, thoroughly washed, processed through flattening solution and dried without pressing, rolling, or excessive heating, and trimmed to the image area, approximately 9: x 9:, with imaged fiducial retained on the print.

4.14. Photographic Index. The Contractor shall prepare a photograph index for each mission. The index shall be on one or more sheets (maximum photo image size: 26" x 30"), and shall be a stable base film positive made from a single negative, entirely free of splicing and marking. Each sheet shall display a north arrow, sheet index with photograph numbers and title block, showing the following information:

Installation Name

Contract No.

Date of Photography

Scale of Original Photography

Contractor Name

Sheet No. _____ of

4.15. Materials. All materials, supplies, or articles required for work described herein shall be products of reputable manufacturers and entirely suitable for the intended purpose. They shall be new and unused, unless otherwise specified.

4.16. Aerial Film. Aerial film shall be furnished by the Contractor of a quality that is equal or superior to Aerocolor Type 2445 or color negative film. Only fresh, fine-grained aerial film shall be used. The negatives shall be exposed and developed in such a manner that they will be sharp, clear, and contain all highlight, and shadow detail. They shall be free of any defects which render them unsuitable for their intended purpose.

4.17. Terrain Elevation Variances. When ground heights within the area of overlap vary by more than ten percent of the flying height, a reasonable variation in the stated overlaps shall be permitted provided

that the fore and aft overlaps do not fall below *(55 percent and the lateral sidelap does not fall below *10 percent or exceed *50 percent.) In extreme terrain relief where the foregoing overlap conditions are impossible to maintain in straight and parallel flight lines, the gaps created by excessive relief may be filled by short strips flown between the main flight lines and parallel to them.

4.17.a. Strips running parallel to shoreline may be repositioned to reduce the proportion of water covered, provided the coverage extends beyond the limit of any land feature by at least 10 percent of the strip width.

4.17.b. Where the ends of strips of photography join the ends of other strips or blocks flowing in the same general direction, there shall be an overlap of at least two stereoscopic models. In flight lines rephotographed to obtain substitute photography for rejected photography, all negatives shall be exposed to comply with original flight specifications, including scale and overlap requirements. The joining end negatives in the replacement strip shall have complete stereoscopic coverage of the contiguous area on the portions not rejected.

4.17.c. Unexposed film. Whenever any part of an unexposed roll of film remains in the camera, before such film is used on a subsequent day, a minimum 3-ft. section of the roll of film shall be rolled forward, and exposed, immediately preceding the beginning of photography.

4.17.d. Quality of Photography. The photographic negatives shall be taken so as to prevent appreciable image movement at the instant of exposure. The negatives shall be free from static marks, shall have uniform color tone, and shall have the proper degree of contrast for all details to show clearly in the dark-tone areas and high-light areas as well as in the halftones between dark and light. Negatives having excessive contrast or negatives low in contrast may be rejected.

4.17.e. Processing of exposed film. The processing, including development and fixation and washing and drying of all exposed photographic film, shall result in negatives free from chemical or other stains, containing normal and uniform density, and fine-grain quality. Before, during, and after processing, the film shall not be rolled tightly on drums or in any way stretched, distorted, scratched, or marked, and shall be free from finger marks, dirt or blemishes of any kind. Equipment used for processing shall be either rewind spool-tank or continuous processing machine, and must be capable of achieving consistent negative quality specified below without causing distortion of the film. Drying of the film shall be carried out without affecting its dimensional stability.

5. GROUND SURVEY AND GLOBAL POSITIONING SYSTEM SURVEYING:

5.1. Ground Control:

5.1.a. Field surveys will be of third order accuracy (1:5,000) or better. Vertical control shall be based on U.S. Coast and Geodetic Survey sea level datum and the horizontal control shall be tied to the applicable State Plane Coordinate System. The distribution of control to maintain mapping accuracy=s as specified, following, shall be the responsibility of the contractor.

5.1.b. All horizontal angles along the traverse routes will be measured with a one (1) second Theodolite utilizing a minimum of three (3) circle positions. The angle derived from each circle position will be obtained from observations with the instrument in both the direct and reversed telescope positions. Should any of the three circle positions produce an angle that differs from the mean by more than six (6) seconds, additional circle positions will be observed until this criteria is satisfied.

5.1.c. Zenith Angles will be measured at each instrument station. These angles will be used to reduce the slope EDM distances to the Horizontal and to compute elevations for each traverse station. Zenith Angles will be observed with the instrument in both the direct and reversed telescope positions to the station forward and to the station back. Zenith Angles for all traverse legs, which exceed 2000 feet in length, will be measured a second time from both ends of the line.

5.1.d. All distances will be measured with an electro/optical EDM capable of measuring at least two (2) miles. The EDM will be calibrated along with the Retro-Reflectors to be used during the survey to determine the proper reflector constants to be applied to each measurement. Temperature and barometric pressure will be recorded for each measurement. Each measured distance will be reduced to a Horizontal Geodetic Sea Level distance and then be reduced to a grid on the Georgia West Zone, Transverse Mercator State Plane Coordinate System.

5.1.e. Astronomical observations for Azimuth will be performed at the beginning and ending of all traverse routes, at or near all traverse junctions. These observations may be made utilizing either the sun or the star APolaris.≅ If the sun is used the AHour Angle≅ method of computation for Azimuth must be utilized. Azimuth adjustment between astronomical observations shall not exceed the square root of the number of stations (N) multiplied by twenty (20) seconds. (Nx20)

6. Mapping shall conform to the following accuracy:

6.1.a. Vertical: ANinety percent of all contours shall be within 1/4 contour interval of their correction position. The remaining 10 percent shall not be in error by more than one contour interval.≅

6.1.b. Horizontal: ANinety percent of all identifiable horizontal features shall be within 1/40 of map scale, their correct position as determined from the nearest grid lines and the remaining 10 percent shall not be more than 1/20 of map scale in error.≅

6.1.c. The Contractor shall furnish plottings of the ground control profiles over which the appropriate mapping profile has been superimposed. Above ground features, such as small structures, manholes, hydrants, valves, and inlets, etc., may be coded by the Contractor as is necessary for his work, either by applying removable panels or by painting with water soluble paint prior to the acquisition of the aerial photography, in order to locate these features during the mapping process. Extreme care must be taken by the Contractor regarding the use of paint. Air Force installations must maintain a neat and orderly appearance and the Contractor must use the least durable paint possible which will, however, permit the successful accomplishment of his work. Any panels, paint, or other images to be placed on the installation=s property shall be approved both in writing and in advance by the Project Manager.

6.2. GPS Methods and Procedures: Comprehensive Planning and environmental data shall use global positioning system (GPS), where appropriate. They system shall be compatible with the Magellan GPS NAV 5000 PRO. Accuracy=s associated with GPS collection methods will be at least three (3) meters. Better accuracy=s may be achieved but are not guaranteed.

6.3. GPS field techniques will consist of double-differentiated. This technique will require a GPS base unit to be located at a known (horizontal and vertical) control point and one or more GPS units at remote or unknown points. To achieve the accuracies specified above, post processing computer software will yield accuracies that are less than 3 meters and require the base station to be manned full time. This technique also required radio contact between the manned base station and the remote site(s) during the observation period. Field differential methods will not be used.

6.4. Equipment required to perform double difference differential GPS methods and to achieve three (3) meter accuracies will consist of the following:

6.4.a. GPS base unit which shall be an Ashtech XII Ranger or other receiver that is compatible with the Magellan GPS NAV 5000 PRO.

6.4.b. Each CONSULTANT furnished GPS unit will consist of the following equipment:

Magellan NAV 5000 PRO

Multipath Antenna

External Data Logger

6.5. The CONSULTANT will require a full-time GPS coordinator to manage the GPS efforts, ensure the quality of the data being collected and to process the data on a daily basis. The CONSULTANT shall be responsible for acquiring the necessary hardware and software for the post processing of the data.

6.6. All work will be accomplished in accordance with the specifications provided in NAVSTAR Global Positioning System Surveying, US Army Corps of Engineers, Engineering and Design, EM-1110-1-1003.

7. Aerial Photography.The Contractor shall furnish all personnel, plant, equipment, transportation, and materials necessary to perform aerial photography in accordance with the following conditions, provisions, and specifications.

8. Camera Equipment:

8.1. All mapping photography shall be made with a single lens precision aerial mapping camera equipped with a Ahigh-resolution, distortion-free≅ type lens, shall be calibrated by the National Bureau of Standards or an agency making calibrations of equal accuracy and shall be approved by the project manager. A copy of the Report of Test of Lens and Camera Calibration Report shall be furnished to the project manager prior to executing the photography mission.

8.2. The calibrated focal length of the lens (the focal length at which the values of the lens distortion, irrespective of sign, are held to a minimum within 45 degrees of the optical axis) shall be 153 millimeters, plus or minus 3 millimeters. The camera shall function properly at the necessary altitude and under the expected climatic conditions, and shall expose a 9-inch square negative. The lens cone shall be so constructed that the lens, focal plane at calibrated focal length, fiducial markers, and marginal data markers comprise an integral unit are otherwise fixed in right orientation with one another.

8.3. Dimensional change brought about by variations of temperature or other conditions shall not be of such magnitude as would cause deviation from the calibrated focal length in excess of plus or minus 0.03 millimeter or would preclude determination of the principal point location to within plus or minus 0.03 millimeter.

8.4. The focal plane surface of the platen shall be flat to within 0.013 millimeter and shall be truly normal to the optical axis of the lens. The camera shall be equipped with means of holding the film motionless and flat against the platen at the instant of exposure.

8.5. For mapping photography, the camera shall be equipped with a minimum of four fiducial marks suitable for making precise measurements in analytical aerotriangulation processes. The lens, focal plane, and fiducial marks must be permanently fixed in rigid orientation with each other. Fiducial marks shall be calibrated to 0.0002 millimeter.

8.6. As referred to the calibrated focal length, the radial distortion shall not exceed plus or minus 1.0 millimeter within a 42.5 degree half field angle, and the tangential distortion shall not exceed 0.0005 millimeter. Values of distortion at equal but opposite angular separations from the axis along the same diameter shall not differ from each other by more than 0.02 millimeters.

8.7. When installed in the camera, and with an appropriate filter mounted in place, the lens shall resolve at least 32 equally spaced lines to the millimeter in the center of the field and at least 14 equally spaced lines to the millimeter in any orientation extending to 45 degrees from its axis, all as could be determined by tests using Eastman Spectroscopic Type V-F Emulsion or equivalent. The lens shall be fully color corrected for color photography.

8.8. The appropriate filter shall be used in the photography and shall be of such quality that no appreciable reduction in resolution will result. The surfaces of the filter shall be parallel to within 10 seconds of arc. Clear antivignetting filters and haze filters shall be used as required for color photography.

8.9. The camera shall be equipped with a between-the-lens shutter of the variable speed type, whose efficiency shall be at least 75 percent at the fastest rated speed.

8.10.Substitute cameras may be used in taking special purpose aerial oblique photographs for the reference and photographs to be used in the preparation of mosaics.

9. SCALE OF PHOTOGRAPHY The aerial photography shall be performed at a flight height above ground elevation so that the film negatives will have a scale as specified below. Negatives having a departure from the specified scale by more than 5 percent because of tilt or abrupt changes in flying altitude shall be replaced.

Area	Negative Photo Scale	Map Scale	Contour Interval
Cantonment Area	_____	_____	
Vicinity Area (Non Cantonment Area)	_____	_____	

10. PHOTOGRAMMETRIC MAPPING REQUIREMENTS Photogrammetric mapping shall be produced from photography meeting the specifications outlined in previous sections. Enlargement from photographic negative scale to compilation scale must be accomplished within the limits of stereoplotter capabilities in order to produce mapping of the required accuracy=s specified in Section _____.

10.1.1. Operators of photogrammetric mapping equipment shall be trained and skilled to meet contract requirements.

10.1.2. Aerotriangulation for control shall be accomplished by fully analytical methods. The positional accuracy (vector of both Northing and Easting coordinate errors) of pass points established by aerotriangulation should meet either of the following minimum requirements:

10.1.a. A root-mean-square error in feet not greater than one part in 1,500 of the nominal negative scale as expressed in feet per inch.

10.1.b. Ninety percent of the checkpoints in error in feet by not more than one part in 900 of the nominal scale as expressed in feet per inch.

In either case, no point should be in error by more than one part of 400 of the negative scale as expressed in feet per inch. At the scale of photography selected by the Government for this project, the pass points should have the accuracies shown below:

PASSPOINTS ACCURACY REQUIREMENTS

Photo Scale	1"=1,600'	1"=400'
RMS (1:1,500)	1.33'	0.40'
90% (1:900)	2.22'	0.67
Max (1:400)	5.00'	1.5'

10.2. Stereo compilation shall be accomplished by using automated stereoplotting devices connected directly to a CADD system, and shall be capable of attaching non-graphic data to a graphic element. The stereoplotting device shall be capable of capturing the level of detail required from the aerial photography. All data shall be digitally derived using an analytical plotter. Stereoplotters and other mensuration instruments shall be well calibrated.

11. Unless otherwise specified, all photogrammetric mapping will meet the following horizontal and vertical accuracy requirements:

11.1. Contours - Ninety percent of the elevations determined from the solid line contours of the topographic maps shall have an accuracy with respect to true elevation 1/2 of the contour interval or better and the remaining 10 percent of such elevations shall not be in error by more than one contour interval. In checking elevations taken from the map, the apparent vertical error may be decreased by assuming a horizontal displacement of 1/20 of an inch. In densely wooded areas where heavy brush or tree cover fully obscures the ground, they shall be plotted as accurately as possible from the stereoscopic mode, while making full use of spot elevations obtained during ground control surveys and all spot elevations measured photogrammetrically in places where the ground is visible.

11.2. Coordinate Grid Lines - The plotted position of each plane coordinate grid shall not vary by more than 1/100 of an inch from true grid value on each map manuscript.

11.3. Horizontal Control - Each horizontal control point shall be plotted on the map manuscript within the coordinate grid in which it should lie to an accuracy of 1/80 of an inch of it's true position as expressed by the coordinates computed for the point.

11.4. Planimetric Features - All planimetric features which appear on the photographs shall be plotted so that at least 90 percent of their positions on the finished maps shall be accurate to within a total range of 1/40 of an inch of their true coordinate positions, as may be determined by test surveys, and none of the features tested shall be misplaced on the finished map by more than 1/30 of an inch from their true coordinate position.

11.5. Spot Elevations - Ninety percent of all spot elevations placed on the maps shall have an accuracy of at least 1/4 of the contour interval, and the remaining 10 percent shall not be in error by more than 1/2 of the contour interval.